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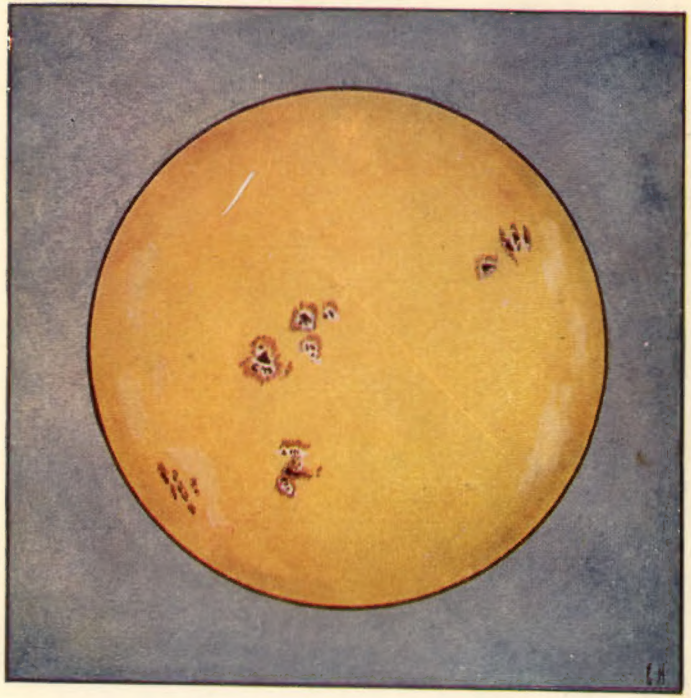
Why did not somebody teach me the constellations, and make me at home in the starry heavens . . ."

CARLYLE.



THE SUN, SHOWING SPOTS AND FACULÆ.
(From a painting by Ellison Hawks.)

THE STARRY HEAVENS

BY

ELLISON HAWKS
Fellow of the Royal Astronomical Society

AUTHOR OF:

"The Romance and Reality of Astronomy"
"The Triumph of Man in Science and Invention"
"The Earth" (*Shown Series*)
"The Book of Natural Wonders"

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ABOUT THIS BOOK

THIS little book has been written in the hope that it will prove of service in introducing the reader to our heritage in the stars. Some people think of astronomers as men with long beards and cone-shaped hats who spend their days in the company of logarithms solving problems in higher mathematics! On the contrary, many of our astronomers are keen young men who are capable of discussing batting averages or enjoying a round of golf like any other normal person. To know something about the heavenly bodies does not mean that one must have a large acquaintance with the technicalities of Astronomy. It is not necessary to be a botanist to be able to appreciate the beauty of a garden—and how few people know the names of the bright stars as they know the names of our choicest flowers! What can add more to the beauty of a walk on a clear winter's night than the companionship of the stars, available to those who know their names and who look for their risings and their settings throughout the seasons. Astronomy offers so many entrancing pathways to pleasure that he who learns to know his stars will not only enrich his interest in the works of the Creator, but also will increase his store of knowledge to an amazing degree.

It has been my endeavour not only to make this book an introduction to the starry heavens, but to make it one that will be continuously useful by introducing a series of star maps showing the heavens throughout the year.

It is not a simple matter to construct a star map, for a sphere has to be depicted on a plane surface. This difference should be borne in mind in comparing the maps with

the heavens when tracing out constellations. The centre of the top of each star map represents the sky overhead; and the north and south maps overlap to the east and west. Approximately, the two maps for any given hour, if cut out and pasted on the inside of an inverted bowl, would represent the whole sky. The times used throughout are Greenwich Mean Time, and adjustment must be made for Summer Time when necessary. (Summer time commences on the third Sunday in April and extends to the first Sunday in October.)

I have to thank those friends who have so kindly assisted with the illustrations: Professor E. E. Barnard; the Astronomer Royal; the Directors of the Lick, Mount Wilson, and Yerkes Observatories; Mr. E. W. Barlow; Mr. W. J. Lockyer; Mr. John Murray; Professor E. C. Pickering; M. Puiseux; Mr. W. H. Wesley; and Professor Max Wolf.

The present is the second edition of this book, the first having been published in 1910. It is a pleasure to be able to express my thanks to my friends Mr. J. M. Field, F.R.A.S., of the City Observatory, Edinburgh, and to Mr. W. H. McCormick, for kindly reading through the proofs of this second edition, as they did when the first appeared.

Many parents and children have written, saying how helpful the little book has been to them. To all these I would say how I have appreciated their letters—they have encouraged me to re-write the book, which I trust in its new form will be as useful as its predecessor.

ELLISON HAWKS.

"DOVERCOURT,"
AINSDALE, LANCS.
December 1933.

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THE STARRY HEAVENS

CHAPTER I

THE SUN'S FAMILY OF PLANETS

WE are always glad to see the Sun shining through our bedroom window on a spring morning, not only because it is warm and bright, but also because it heralds the approach of summer. The trees and plants are glad, too, when the Sun shines on them, for it means new life to them after the long and cold winter. Sunshine is indeed very important to all living things —without it there could be no life on the Earth. The Sun continually sends out rays of heat and light, and rays of other kinds from which probably we benefit very considerably.

The Sun is the centre of a family of worlds, or planets. Our Earth is a member of this family, and there are eight other planets as well, forming what is called the Solar System. Each planet travels around the Sun in its own path or orbit. Some of these orbits are comparatively near to the Sun, others are farther away. The orbit of the Earth lies a great way off from the Sun, but yet not so far away as the orbits of some of the other planets. (See Plate XII.)

The planet nearest to the Sun is Mercury, then follow in order of distance, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. So that you may be able to remember more easily the order of the planets, I have made up the following sentence :

Men	Very	Easily	Make	Jugs
Mercury	Venus	Earth	Mars	Jupiter

Serve	Useful	Necessary	Purposes
Saturn	Uranus	Neptune	Pluto

You will notice that in this sentence the initial letters of the words are the same as the first letters of the planets in their correct order. Two of the names of the planets begin with the letter M, and in order that you will not get these two mixed up, I have made the first word, standing for Mercury, begin with Me . . ., as does the planet's name. In the same way, the word corresponding to Mars begins with Ma . . .

The Sun attracts the planets by an invisible force that exists throughout the universe. This force of attraction, which is called gravitation, keeps the planets from wandering away from their paths. The law of gravitation was discovered by Sir Isaac Newton, one of the cleverest men the world has known. Newton was born on Christmas Day, 1642, at the village of Woolsthorpe, near Grantham, Lincolnshire. The story goes that whilst sitting in the orchard at Woolsthorpe he saw an apple fall to the ground. He asked himself why the apple should fall downwards instead of upwards,

and having thus been set wondering he did not rest until he had found the explanation.

We have said that each planet travels, or, as astronomers say, revolves, around the Sun. Most of the planets have smaller bodies revolving around them. These small bodies are the planet's moons, or "satellites" as they are called. They are so called from the Latin word *satilles*, meaning "an attendant," and you will agree that this is a very suitable name for them. Now you will understand what is meant when the Moon is called the Earth's satellite.

Besides revolving around the Sun, the planets have also another movement. We are all familiar with a globe, representing the Earth, fixed on a stand and having painted on its surface a representation of the continents and oceans. This globe, which is held in position by a metal rod running through its centre, can be made to spin round. This spinning movement is called rotation, and the rod is known as the axis. Thus when it is spinning, the globe is said to be rotating on its axis. Each of the planets rotates on its axis in a similar way to the schoolroom globe, but in their case there is no actual rod to form an axis, which is only an imaginary one.

CHAPTER II

THE SUN AND ITS SPOTS

THE Sun is a very large body surrounded by glowing vapours, much in the same way that the Earth is surrounded by its atmosphere. Its volume, or bulk, is over a million times that of the Earth, and many thousands of times greater than that of all the planets together. To gain some idea of its enormous size we may use the following illustration. Supposing we could lay a railway along the Earth's equator, an express train would make a complete circuit of the Earth in less than three weeks. If we could lay a similar railway along the Sun's equator, it would take the express five years to travel once round it. It would require at least 109 globes the size of the Earth, and laid side by side, to reach from one side of the Sun to the other. That is to say, if we represent the Earth by a halfpenny (1 inch), the Sun on the same scale would be represented by a disc measuring over 9 feet in diameter.

Often when we look at the Sun with a telescope we can see faint streaky white markings. These are called "faculæ," which is a Latin word meaning "little torches." Although sometimes the faculæ do look like torches to us, actually they are mountainous clouds of

fiery gas. If you look at the frontispiece of this book, you will see some of these faculæ near the edge of the Sun.

The telescope also shows us spots on the Sun's surface. (See Plates I. and II.) These are surrounded by a "penumbra," or kind of fringe, as is clearly seen around the large spot in Plate IV. Near the centre of the photograph of the Sun reproduced in Plate I. you will see a group of several spots, and near the right-hand edge there is a single spot. Look now at Plate II., which is another photograph of the Sun taken five and a half weeks later, and you will notice that the spots have changed. The big group has vanished, and there is now a group lower down and near the left-hand edge, whilst another group of spots is to be seen higher up on the right.

These changes are due to the fact that the Sun turns, or rotates, on its axis exactly as the Earth does. We all know that the Earth rotates once in twenty-four hours, and that it is this movement that causes day and night. The Sun rotates once in about twenty-seven days, and the spots turn as well because they are part of its surface. We cannot see the whole of a ball at one time, nor can we see the whole of the Sun at one time. When we look at the Sun through a telescope we see spots first at the right-hand edge (or "limb," as it is called), and then day by day we notice that they move a little farther to the left. Having reached the centre, they gradually travel towards the opposite limb, and at length disappear around it.

When the spots are near the limb of the Sun we see

them edgeways on, as it were ; but as they move nearer to the centre we see them "full in the face." Suppose we get a large ball and fasten a penny to it, and ask a friend to slowly turn the ball. If we stand some distance off and watch the ball turning, we see the penny gradually come into sight from the back of the ball. First of all, we see only the edge of the penny, looking like a thin line and not at all like the round coin it is. Then gradually, as our friend turns the ball, the penny seems to become more circular in shape, until, when it has reached the centre of the ball and is opposite to us, it appears to be quite round. It is exactly the same with the sunspots. In Plate III. you will see a large sunspot almost at the edge of the Sun, and in the next picture (Plate IV.) the same spot seems to be more circular because it is nearer the Sun's centre.

Now, what are sunspots? We have seen that the Sun is surrounded by a covering envelope of gases. This is called the photosphere, from two Greek words, *photos*, meaning "of light," and *sphaira*, "a globe." Thus the photosphere is the globe that gives light, and the spots appear to be openings in it. When we look into a spot we seem to be looking through a great hole in the bright surface of the Sun. This is indeed the case, for terrific storms, which are always raging on the Sun, cause great breaks in the photosphere, exactly as the wind will often cause a break in the heavy rainclouds in our sky.

Sunspots vary both in number and size. Sometimes there is scarcely any to be seen, but at other times there may be several. A peculiar fact about them is that they are more numerous at certain times than

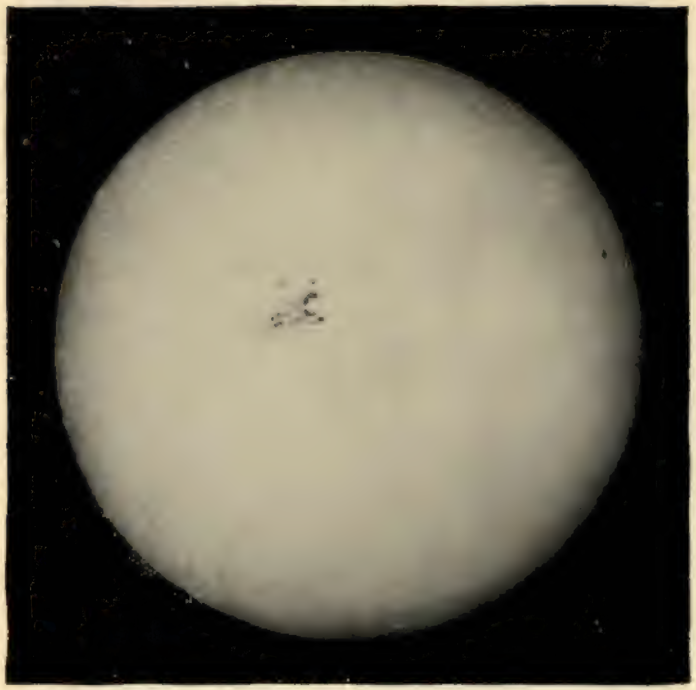

PLATE I.—THE SUN WITH A GROUP OF SUNSPOTS.
(From a photograph by E. W. Barlow, F.R.A.S.)

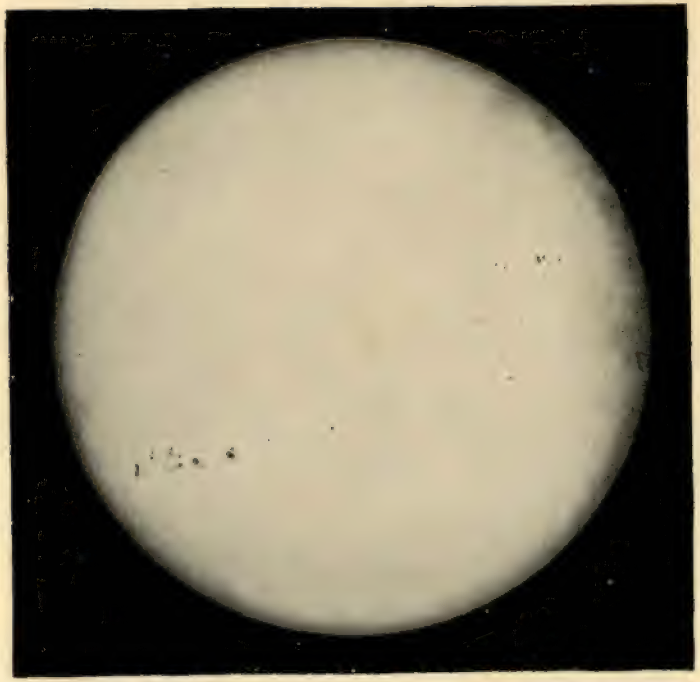

PLATE II.—THE SUN WITH GROUPS OF SUNSPOTS.
(From a photograph by E. W. Barlow, F.R.A.S.)

at others. Their numbers regularly increase and decrease over a period of about eleven years.

Sometimes the spots are so small that it is difficult to see them even with a powerful telescope. On the other hand, occasionally there are spots so large that they can be seen with the naked eye. (Here let me add a word of caution. Whenever you wish to look at the Sun, always take the precaution of protecting your eyes from the dazzling sunlight by looking only through a piece of smoked glass or an old photographic negative.) Although the spots may seem small, they are really enormous, for the Sun is a long way off, and even large objects look small at such a distance. Sometimes a large spot will measure thousands of miles in diameter. In February 1905 there was a spot that was large enough to contain forty worlds each as big as the Earth!

Sunspots do not form instantly like a flash of lightning, but they grow gradually. Before a spot breaks out the astronomer may notice that something unusual is happening in a certain part of the photosphere. He sees faculæ all about some particular region, and their appearance is generally a sign that here a spot will be formed during the course of the next few days.

Nearly all sunspots are round at first, but they gradually lose their circular shape and become twisted into all manner of peculiar forms. After a while—it may be a few days, weeks, or even months—the spot begins to break up. First, bridges of white matter are seen shooting across it (see Plate IV.), and these increase in size and number until they gradually cover over the

spot, which, in the course of time, disappears from our sight.

So things go on, year after year, spots breaking out and being covered over again. There is plenty of work for those astronomers who watch and record their formations and disappearances. A great deal of time is devoted to the study of the Sun, and a most marvellous study it is. Yet many people never give a thought to the wonderful things that are to be seen, and the interesting facts to be learned from them.

THE SUN

Mean distance . .	(about) 92,870,000 miles.
Diameter	(about) 864,000 miles.
Density	less than one and a half times that of water.
Rotation on axis .	(about) 24½ days.
Sizes of sunspots .	from 500 to 150,000 miles in diameter.

CHAPTER III

ECLIPSES OF THE SUN AND MOON

SOMETIMES there takes place what is called an eclipse, a word that comes from a Greek word meaning "to fail." When an eclipse of the Sun or Moon occurs, the light fails; and so you see why eclipses are so called. Eclipses are of two kinds: "partial," in which only part of the light is cut off; and "total," in which all the light is cut off. In the case of the Sun there is a third kind, known as the "annular."

Let us first learn something about eclipses of the Moon. The light of the Sun causes the Earth to throw a long shadow behind it into space, exactly as a ball throws a shadow when held in the light of a lamp. In the course of its journey round the Earth our satellite sometimes passes into this shadow, and is then said to be eclipsed (Fig. 1). Of course, at ordinary times we cannot see the Earth's shadow, and it only becomes visible when it falls on the bright surface of the Moon. Eclipses of the Moon can only take place when the Moon is at the "full," the meaning of which will be explained later. They may be either total or partial, according to whether or not the Moon passes completely into the shadow, or only partly.

Eclipses of the Moon are seen over a much wider area than eclipses of the Sun. They are, indeed, always visible over more than half the Earth. Instead of lasting only for seconds, or a few minutes at the most, they last for about two hours. When the Moon is entirely in the Earth's shadow it appears copper-coloured. It is a wonderful sight to see the full silvery Moon gradually change to one that shines with a dull red light.

Eclipses of the Sun take place when the Moon comes in

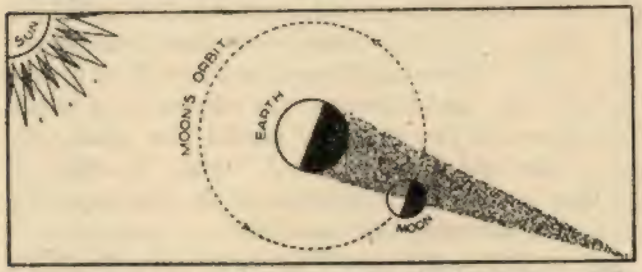

Fig. 1.—Showing the Moon passing into the shadow of the Earth and becoming eclipsed.

between the Earth and the Sun. Every month the Moon, in the course of its journey around the Earth, must pass between the Sun and the Earth. Eclipses of the Sun do not occur every month, however, for generally the positions of the Sun, Moon, and Earth are such that the Moon's shadow does not fall on the Earth, as is illustrated in the upper diagram of Plate V. It is when the Moon is in such a position that its shadow falls on the Earth that an eclipse occurs. This is illustrated in the lower diagram on Plate V., which shows an eclipse that is taking place in South Africa. At the

time of an eclipse we see the dark body of the Moon as it gradually passes in front of the Sun and cuts off the sunlight.

This is shown in Fig. 2, which also shows how the eclipse is caused. The eclipse illustrated in this drawing is a partial eclipse. When the whole of the Sun is hidden by the Moon, it is said to be a total eclipse. Though we may hope to see many partial eclipses of the

Fig. 2.—On the left is shown the appearance of the Sun at a partial eclipse. On the right we see how such an eclipse is caused.

Sun, it is not often that we can see a total eclipse in this country. Although there are two eclipses of the Sun every year, and sometimes three or four, they are generally only visible from countries nearer the equator. The last occasion on which a total eclipse was seen from the British Isles was on 29th June 1927. There will not be another until 11th August 1999, when it will be visible from places in the south-west of England.

A total eclipse is a very wonderful sight, and astrono-

mers willingly travel to far-off parts of the Earth in order to see one. The first thing that is seen is the dark edge of the Moon touching the Sun, as it does at the beginning of a partial eclipse. Gradually, as the Moon travels along, the eclipsed part grows larger and larger until, at last, the Moon has covered the Sun entirely. At this time there is so little light that birds go to roost, and sensitive flowers close their petals, thinking that night has come. After it is over and the Sun shines once more, the birds wake up and the flowers open their petals, to find they have been deceived.

In some countries the uneducated natives are afraid of an eclipse of the Sun, for they do not understand its cause. When they see the Moon creeping over the Sun they think that it is some great monster that is swallowing the Sun. They imagine that by making a great noise they will be able to frighten the monster away, so they beat furiously on gongs, loudly blow horns, and add to the general noise by shouting and wailing. When the eclipse is over, and the dark body of the Moon has passed away from the Sun, they imagine their efforts have been successful and that the monster has been frightened away!

The distance between the Moon and the Earth varies, so that sometimes, when an eclipse takes place, it fails to cover the Sun entirely, which is seen as a narrow ring of light surrounding the dark Moon. Such an eclipse is known as an "annular," from the Latin word meaning "a ring."

The eclipsing of the sunlight during a total eclipse enables us to see a most beautiful sight. All around the

dark body of the Moon is a halo of soft pearly light, called the "corona," a Latin word meaning "a crown." This name is very suitable, for the corona forms a very beautiful crown to the eclipsed Sun. This is well seen in the illustration on Plate VI., and here, too, you will see a streak of silvery light close to the eclipsed Sun. This is a comet, and you will read of these wondrous objects in a later chapter of this book. The comet shown in the picture had not been seen until this eclipse took place, for it was outshone by the dazzling sunlight. It was only when the Moon cut off the Sun's rays that it was discovered.

If you look carefully around the dark body of the Moon in Plate VI., you will see a number of tiny spikes standing out from the edge. These are the prominences of sun-flames, of which enlarged views are given in Plates VII. and VIII. Although they may not appear to be very large, prominences are indeed of enormous size, as you will understand by comparing the white spots on the plates. These spots represent the size of the Earth drawn to the same scale as the prominences. Actually, some of the prominences are so huge that, even were we to place thirty worlds as large as our Earth one on top of the other, the prominences would be even higher! Due to the tremendous distance, it is difficult for us to realize the great size of the prominences of the Sun. As a matter of fact, our distance from the Sun is such that if we could lay a railway from the Earth to the Sun, and start off a fast train along the line, it would take it about 275 years to reach its destination, even though it travelled day and

night! In other words, if King Charles II. had started off in such a train, he would not have reached the Sun yet!

The prominences differ in form, some resembling sharp spikes, as in the top picture of Plate VII. Others resemble fantastic trees, whilst others again closely resemble the flames of our firesides. Sometimes prominences are seen detached, floating above the surface of the Sun as clouds float above the Earth.

Until the year 1868 the prominences could only be seen at the time of a total eclipse. In that year, however, two astronomers, Janssen and Lockyer, found that by the aid of a wonderful instrument (the spectroscope) they could see them at any time, and in broad daylight. This was a great discovery, for astronomers had been able to learn very little about the prominences owing to the fact that they were only visible for a few minutes during an eclipse. Naturally, in such a short space of time, and on such rare occasions, it had not been possible to make many observations. When the spectroscope enabled the prominences to be observed at any time, astronomers were able to study these wonderful objects. It soon became known that the prominences were immense flames of glowing gas (hydrogen), and that probably they were connected with the storms that are always raging on the Sun.

When we look at the Sun calmly shining over some beautiful landscape, or sinking beneath the horizon amidst glorious sunset clouds, we might imagine that of all things it is the most calm and peaceful. This is not the case, however, for our glowing orb is the seat

PLATE III.—SUNSPOTS NEAR THE EDGE OF THE SUN (SEE PLATE IV.).
(*From a photograph by E. W. Barlow, F.R.A.S.*)

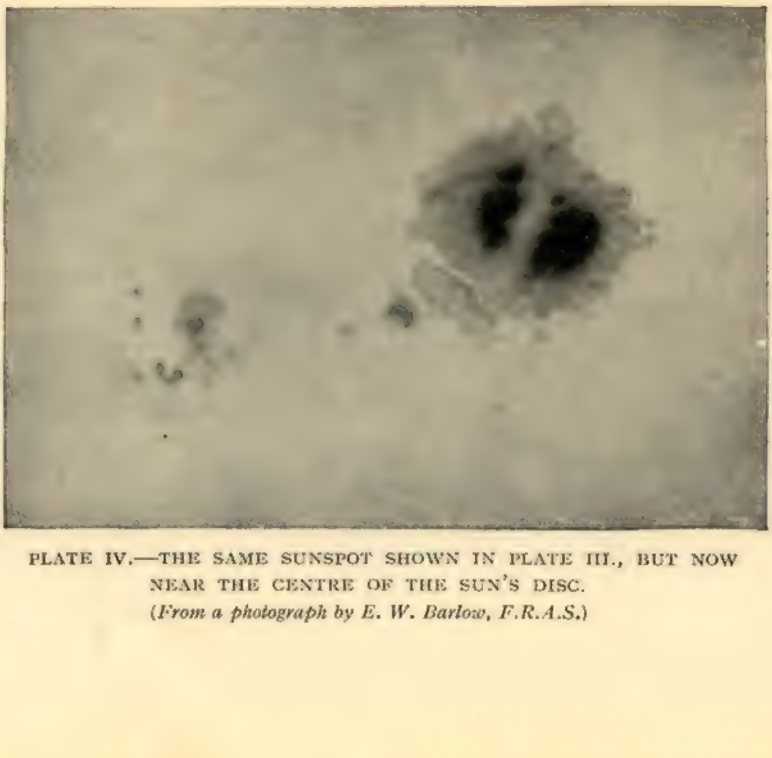

PLATE IV.—THE SAME SUNSPOT SHOWN IN PLATE III., BUT NOW NEAR THE CENTRE OF THE SUN'S DISC.
(*From a photograph by E. W. Barlow, F.R.A.S.*)

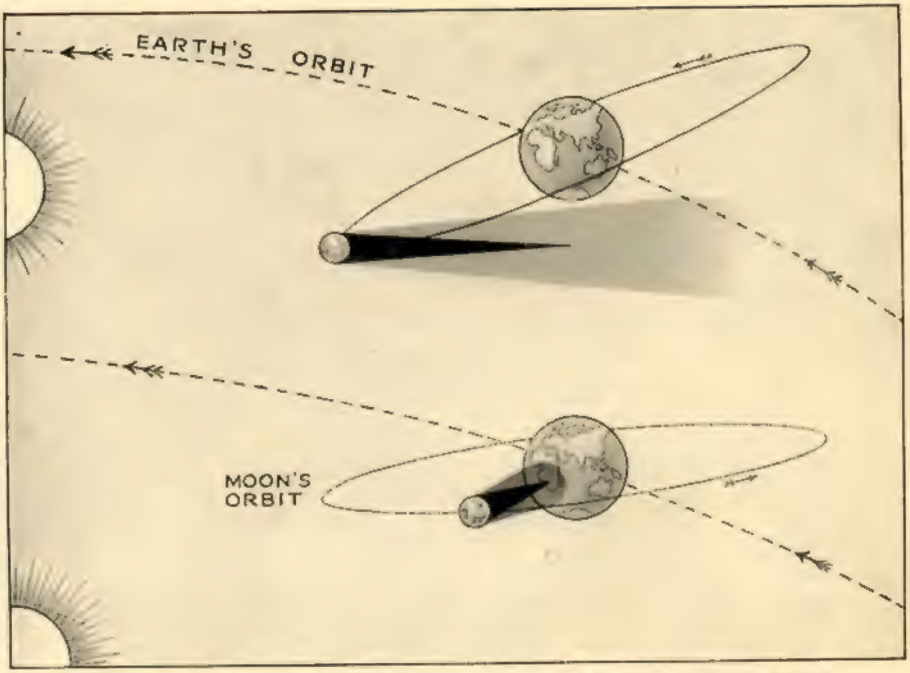

PLATE V.—SHOWING WHY AN ECLIPSE OF THE SUN DOES NOT HAPPEN EVERY MONTH (see page 120).

PLATE VI.—A TOTAL ECLIPSE OF THE SUN.

(From an engraving by W. H. Wesley.)

PLATE VII.—PROMINENCES OR SUN-FLAMES.

The white spot in the top left corner represents the size of the Earth on the same scale.

(From "Astronomical Engravings," by permission of Harvard College Observatory.)

of storms so furious that we can have no idea of their true nature. These solar storms are not made up of wind and rain, as are those on the Earth, but are the movements due to tremendous internal forces. The giant flames are the result, and they possess a heat so intense that it would scorch the Earth to a cinder from a distance of millions of miles. There is no fear of this happening, however, for the distance of the Sun is so great that, although we can feel his heat on a warm summer day, the heat of the prominences themselves is indistinguishable.

CHAPTER IV

THE MOON

WE all appreciate the beauty of the Moon when it is seen as a crescent in the western sky, just after sunset. It looks beautiful, too, in the south when it is "full," and people often may be heard to say, "What a lovely night; it is almost as light as day!" The Moon was of great importance to the people of old, who had no artificial light other than the very crudest. In countries near the equator, where twilight is short, deep darkness soon covers everything after sunset. A moonlight night enabled the labours of the field and of the house to be continued; the Moon lit the way for the traveller; and the shepherd found his toils and his dangers greatly lightened.

Of all the heavenly bodies, the Moon is the Earth's nearest neighbour. It is less than a quarter of a million miles distant, and thirty Earths placed side by side would form a bridge of sufficient length to join the two bodies. An express train, travelling day and night, would make the journey in about six months.

Now I must explain that the Moon is a very different

body from the Sun. It is not highly heated nor gaseous as the Sun is, but is a cold, solid body—a world something like the Earth, in fact, but considerably smaller. It shines by reflecting the light of the Sun. You will no doubt think it strange to find that it is our Sun that lights up the Moon, but such is the case, and if it were not so the Moon would be invisible, for it has no light of its own.

Although the Moon resembles the Earth in many ways, it differs in several respects. The most important difference is that it is a dead world! Its great seas are now all dried up; there are no trees, no flowers, and there even is no air. On the Moon there is no life as we know it—no towns and cities, no people and children. I think none of us would like to live in a world such as this, even if life there were possible.

During the course of each month we notice certain changes take place in the illuminated part of the Moon. Night by night it grows until it is "full," and then its apparent size decreases again. These changes are known as the "phases." When growing the Moon is said to be "waxing," and when decreasing it is "waning." To explain these regular alterations in the Moon's appearance was a problem to the people of old, and there are many people even to-day who do not understand them. The Babylonians supposed that the Moon had a dark and a bright side, and that as she moved through the sky she slowly turned her bright side towards the Earth. It was the Ancient Greek philosopher Aristotle who first gave the correct solution to the problem.

The explanation of the Moon's phases is really not at all difficult. It can best be understood by a simple experiment. If you hold a ball between your eyes and a lighted candle, the light falls on the side of the ball that is turned away from you, and the part of the ball towards you is dark. If, now, you slowly move the ball to one side, the illuminated part will gradually come into view. The candle represents the Sun, and the ball the Moon, the illuminated part of which gradually appears in the same way, as the Moon moves round the Earth. The phases, therefore, are due to the different positions from which we view the illuminated part of the Moon's surface as it moves around the Earth throughout the month.

Fig. 3.—By the help of this sketch you can quickly identify the Lady in the Moon on Plate IX.

When "new" the Moon appears in the west, close to the setting Sun, but you will notice that each evening it appears to have moved a little farther away from the sunset. Sometimes you may notice that the fine crescent of the new Moon seems to be accompanied by a faint illumination of the remainder of the "circle," or the dark part. This is sometimes called

"the old Moon in the young Moon's arms," and is also known as Earth-shine. It is due to sunlight falling on the Earth, whence it is reflected to the Moon, where it faintly illuminates the part of the Moon that is not lit up by the Sun's rays. In other words, the Earth is acting as a huge moon to the Moon, and we see the Earth-light lighting up the dark surface of our satellite. If we could stand on this dark part of the Moon, the Earth would appear as a huge moon in the sky and it would seem to be over twelve times as large as the full Moon appears to us.

You will have heard people speak jokingly of "the Man in the Moon," and although you know that this man does not exist, it is true that some of the markings on the Moon really do seem to represent fanciful figures. One of the best-known of these, the "Lady," is to be seen on Plate IX., and by the aid of Fig. 3 you will be able to find her for yourselves. I should like you to look at the Moon some clear night, and try to make out the Lady, for it is easy to see her without a telescope. When the Moon is "full" you can see also "the kiss" —the Lady kissing the cheek of a person whose back is to us. Then there is also a delightful representation of one of those curious-looking dogs, a French poodle. The poodle's head and body are formed by the Lady's hair; his front legs may be seen quite clearly—he is sitting on his haunches—and also his tail, complete even to the little "pom-pom" on the end!

The Moon has a strong influence on the tides, which are due to the combined action of the Sun and the Moon. When the Moon is "new" and when it is "full," the

attractive power of the Sun and Moon unite, resulting in what are called "spring tides." They are higher than those produced at other times, when the forces are pulling against each other. These latter tides are known as "neap tides."

THE MOON

Mean distance	(about) 238,857 miles.
Diameter	(about) 2,160 miles.
Density	slightly greater than that of the Earth.
Rotation on axis . . .	once a month.
Sizes of lunar craters . .	from 5 to 100 miles.

CHAPTER V

THE MOON MOUNTAINS

YOU all know that when you look at a newspaper through a magnifying glass the print appears much larger. Exactly in the same way, when we look at anything through a telescope, we seem to see it larger, and this enables us to make out features that are invisible to the naked eye. When the night is fine, and the clouds are not in the way, I open my observatory and take off the covering that keeps the dust from the telescope. Then I point the instrument to the Moon and look through the eyepiece. I wish you could look with me, for the sight is very wonderful. All over the Moon's surface I can see dried-up seas, great mountain ranges, enormous walled plains, and thousands of curious ring-like objects called "craters" (Plate IX.).

In order that astronomers might "find their way" about the lunar landscape, it became necessary to name the various regions. It must be confessed, however, that in the case of the "seas" the names chosen do not seem to be very pleasing. Some are very odd, whilst others are melancholy. For example, we have such peculiar names as the Sea of Anger, the Ocean of Storms, the Marsh of Mists, the Sea of Crises, the Sea of Rains, the Lake of Death, and so on. Some of the mountains are named after the mountains of the Earth, and most

of the craters are named after famous astronomers. For instance, there are the Apennines, the Pyrenees, and the Carpathian mountains. There are craters bearing the names Aristotle, Copernicus, Plato, Tycho, Kepler, Newton, and Ptolemy, all of which are names of learned men who lived long ago. Astronomers have devoted a great deal of time to studying the Moon, and several maps of it have been made. It has been said that we know the Moon's surface even more accurately than the surface of the Earth. This is because we have not yet seen all the features of the Earth's surface, but the details of the Moon may be seen any clear night with the aid of a telescope.

When we look through a telescope at the Moon, it seems as though we are looking down at it from above. We are, in fact, getting a bird's-eye view, and so the crater rings appear something like, say, Wembley Stadium looks as seen from an aeroplane. Looking at Plate IX. you will notice, about half-way down on the left-hand side near the white x, a crescent that seems to be all by itself, surrounded by darkness. This is Copernicus, a great plain surrounded by a high wall of mountains. Copernicus is so large that it can be seen distinctly with the naked eye. Turn now to Plate X. You can easily imagine that you are looking down on this great walled-plain from an aeroplane flying far above the Moon's surface.

When this photograph was taken, the Sun had just risen on Copernicus, and is shining from the left-hand side. At sunrise and sunset the mountains cast long black shadows on the lunar surface. The black marking,

PLATE VIII.—A HUGE SOLAR PROMINENCE EXTENDING TO A HEIGHT OF 140,000 MILES.

The white spot represents the size of the Earth.

PLATE IX.—THE MOON, SHOWING SOME OF THE NUMEROUS "SEAS," WALLED PLAINS, AND CRATER RINGS.
(From a photograph by P. Puiseux.)

PLATE X.—THE GREAT WALLED-PLAIN COPERNICUS.
The Carpathian Mountains are towards the bottom of this photograph.
(*From a photograph taken at the Yerkes Observatory.*)

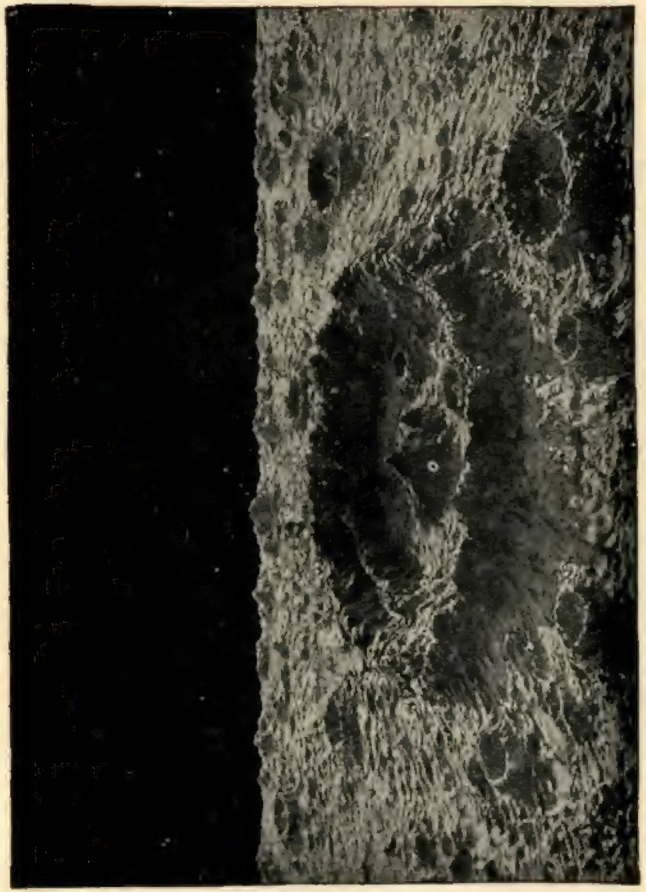

PLATE XI.—A MODEL TO ILLUSTRATE A TYPICAL VIEW ON THE MOON.

in the form of a rough crescent, seen inside Copernicus in our illustration, is the shadow cast by the left-hand wall on the floor of the plain. There are large numbers of walled-plains and crater rings similar to Copernicus, and they are of all sizes. Some are as large as Yorkshire—the largest county in England—while others are small in comparison. For instance, you will see in Plate X., to the left of Copernicus, a number of tiny depressions, some scattered over the surface of the Moon and others arranged in a long string.

There have been many stories written of imaginary journeys to the Moon, and these date from as early as the second century. Lucian of Samosata, a Greek writer, described how his hero's ship was caught up in a water-spout and carried into space. After seven days and nights the sailors landed on a round island that proved to be the Moon, and here they had many strange adventures. Some of the inhabitants of the Moon were mounted on gigantic fleas as big as a dozen elephants! The people there did not eat, but merely inhaled the fumes of roast frogs! The great astronomer Kepler wrote of his *Dream Journey to the Moon*, and the English Bishop Godwin, in 1638, told of a voyage to the Moon in an aerial chariot drawn by wild geese! One of the best stories, however, is *From the Earth to the Moon*, by Jules Verne, which probably many of you will have read and enjoyed.

In recent years there has been some talk of firing a giant rocket to the Moon, with people inside. Even if the rocket did reach the Moon it would be impossible for the passengers to return to the Earth, so it would

not be a very cheerful voyage, would it? If we were able to make such a journey and to look at the "country" when we arrived near our destination, we might expect to see something resembling the view given in Plate XI. Towards the centre of the picture you will see a large crater, in the middle of which rises a conical mass not unlike a great mountain peak. Numerous smaller craters and depressions may be seen scattered around. Notice, too, the shadows cast by the distant walls of the craters. You will see that the surface of the Moon is quite barren. Actually there must be a death-like stillness over everything, for there is no life there. What a great difference there is between the Moon and the Earth, the surface of which is covered with vegetation, water is to be found in abundance, and the valleys are filled with trees and animal life.

Several theories have been put forward to account for the great lunar craters. At one time it was thought that the peaks in the centre of the crater rings were once great volcanoes, shooting forth stones and lava, as Vesuvius, Etna, and other volcanoes on the Earth sometimes do to-day. It was supposed that these great masses of stones and rocks had been thrown high into the air, to fall back to the surface of the Moon. Thus they formed rings around the central peaks, in a somewhat similar way to that in which the fountains in our parks throw up water. If you are able to see one of these fountains "playing," as it is called, you will notice that the water falls in a ring around the jet of the fountain. According to another theory, the crater rings were formed by meteorites colliding with the Moon, and

this is now accepted by most astronomers as being a more likely explanation than the earlier one.

In many cases we know exactly how high the Moon mountains are, and I daresay you will be puzzled to know how it is possible to measure the mountains of another world. You will know that a flagstaff throws a shadow when standing in the sunlight. Any one clever at figures could very soon tell how high the flagstaff is, without bothering to climb to the top to measure it with a tape measure! He would measure the length of the shadow, and then, by a simple calculation that takes into account the position of the Sun in the sky, he would be able to give the height of the flagstaff. As we have seen, the Moon mountains throw shadows too, and astronomers have measured the length of these shadows. Exactly as it is possible to tell how high the flagstaff is, so, too, can the astronomer calculate the height of the lunar mountains. They are found to be much higher in proportion to the size of the Moon than are those of the Earth. One of the peaks of the Dörfel Mountains, near the South Pole of the Moon, rises to a height of 26,000 feet, or nearly five miles.

To all who have telescopes the Moon is a most interesting study. Even a pair of opera-glasses or field-glasses will show many of the craters distinctly, whilst with a small telescope there is much to interest us every night. It is one of the most beautiful sights imaginable to watch the sunrise on the lunar mountains. Many astronomers spend a great deal of time drawing and measuring the craters, while others photograph the Moon under different aspects.

CHAPTER VI

MERCURY AND VENUS

WE have seen that there are other planets besides the Earth that also depend on the Sun for light and heat. We cannot say whether or not there are people living on any of these other planets, for although our telescopes magnify a great many times, even the nearest planet is so far away that the largest telescopes in the world could not show us living creatures—supposing that they are there!

In Plate XII. you will see a plan of the orbits of the planets of the Solar System, but this is not drawn to scale. In the centre is a dot that represents the Sun, and around it is the path of Mercury, the planet nearest to the Sun. Next comes the path of Venus, and it is of Mercury and Venus that I am now going to write.

In addition to being the nearest planet to the Sun, Mercury is also the smallest planet of the Sun's family. The diameter of the Earth is about 8,000 miles, but that of Mercury is only about 3,000 miles. Although it is not often seen, because it keeps close to the Sun, Mercury must have been known from the earliest times. The astronomers of Nineveh mention the planet in a report that they made to Assurbanipal, one of the famous

kings of Assyria. The planet was certainly known to the Greeks, for they called it "the Sparkling One."

To the naked eye Mercury appears as a fairly bright star, either immediately after sunset or early in the morning before sunrise, and is best seen in the clear air of the country. It can only be seen at certain times of the year when it is at its greatest distance from the Sun. Mercury is so close to the Sun that were we able to visit the planet we should find the Sun appeared to be over five times as large as it does to us on the Earth. It would be uncomfortably hot!

Venus seems to make up for Mercury's lack of brightness, for it is the brightest of all the planets. It is a most lovely object, outshining all other heavenly bodies, except the Sun and the Moon. Indeed, its dazzling radiance makes even the brightest stars appear pale and insignificant. When Venus happens to be in our evening skies about Christmas time, people think that it is the star of Bethlehem come again. This is not so, however, for although no one knows what the star of Bethlehem really was, it certainly was not Venus. You will remember we are told that the star of Bethlehem moved along in front of the wise men of the East, and of course Venus, or any other heavenly body, could not move about in that manner. Venus was known and admired in the earliest times—indeed, some astronomers believe that it is mentioned under the name of Mazzaroth in the Book of Job.

As with Mercury, Venus also is sometimes seen in the mornings and sometimes in the evenings, but neither can ever be seen at midnight. When Venus appears

as an evening "star" it never sets later than three hours after the Sun. The astronomers of old thought the morning and evening appearances of Venus were due to two separate planets. When Venus was visible before sunrise they called it Phosphorus; and when seen after sunset, Hesperus. Pythagoras of Samos, who lived some 2,500 years ago, was the first to suggest that the two "stars" were the same, and that they were due to Venus being in a different position in its orbit.

Venus is about the same size as the Earth, and the two are often referred to as "sister planets." Venus is a beautiful object as seen through a telescope. It is supposed that its great brightness is caused by clouds that surround the planet and reflect the Sun's light, just as a looking-glass does. Our clouds reflect the sunlight also, and you often will have seen those great white masses of cloud, looking like snow-mountains, reflecting so much light that they dazzle our eyes. The clouds that surround Venus generally prevent us from seeing any markings that may be on its surface. Now and then we can see faint markings, however, as though the clouds sometimes thinned out a little, and allowed us to peep through to see something of the surface of the planet beneath. Some of these faint markings will be seen in Plate XIII.

For the reason that Mercury and Venus come in between the Earth and the Sun, they both resemble the Moon in the fact that through a telescope they exhibit phases. Sometimes they appear as thin crescents of bright silvery light, like the Moon when it is "new." At other times they resemble "half" Moon, or even

"full" Moon. These changes are due to the same cause as that of the Moon's changing shapes, as explained in Chapter IV. The two pictures on Plate XIII. will show you the appearance of Venus as seen at different times, one appearing as a "half" Venus and the other as a thin crescent. It was Galileo who first discovered the phases of Venus with his telescope, and he was very surprised at what he saw.

Occasionally, both Mercury and Venus pass between the Sun and the Earth. This is known as a "transit," from a Latin word meaning "to go over." We see them as small black spots on the disc of the Sun. The transits of Mercury are of less importance than the transits of Venus, which are of great help in measuring the distance between the Earth and the Sun. Unfortunately these transits occur very seldom. The last were on 8th December 1874 and 6th December 1882. There will not be another until 7th June 2004. The last transit of Mercury was in 1914, and the next will take place in 1947.

	MERCURY.	VENUS.
Diameter	3,100 miles	7,600 miles
Mean distance from Sun .	35,950,000 miles	67,170,000 miles
Revolves around Sun in .	88 days	225 days
Rotation on axis . . .	Not yet determined	Not yet determined.

CHAPTER VII

THE EARTH AND MARS

IF you will look again at the diagram of the orbits of the planets on Plate XII. you will see that outside the path of Venus lies that of the Earth, and that beyond this is the path of Mars.

The Earth is a planet just as Venus is, and although the Earth may seem like a great flat field to us, we know that really it is a globe, as are all the other planets. We know also that the Earth travels around the Sun, and takes about 365¼ days to complete one revolution. As you know, 365 days make a year, and so each year there is a quarter of a day left over. In four years, therefore, there will be a whole day extra, and as February is the month with the smallest number of days, it was given the extra day. Every four years, therefore, February has 29 days, and that year is called Leap Year.

Neither Mercury nor Venus has a Moon, so the Earth is different from them in this respect. We have mentioned that the Moon rotates around the Earth and shines by reflecting the light of the Sun. It is difficult to believe that the Earth also reflects light exactly as the Moon does, and as the other planets do. We can scarcely imagine our fields and seas reflecting back the

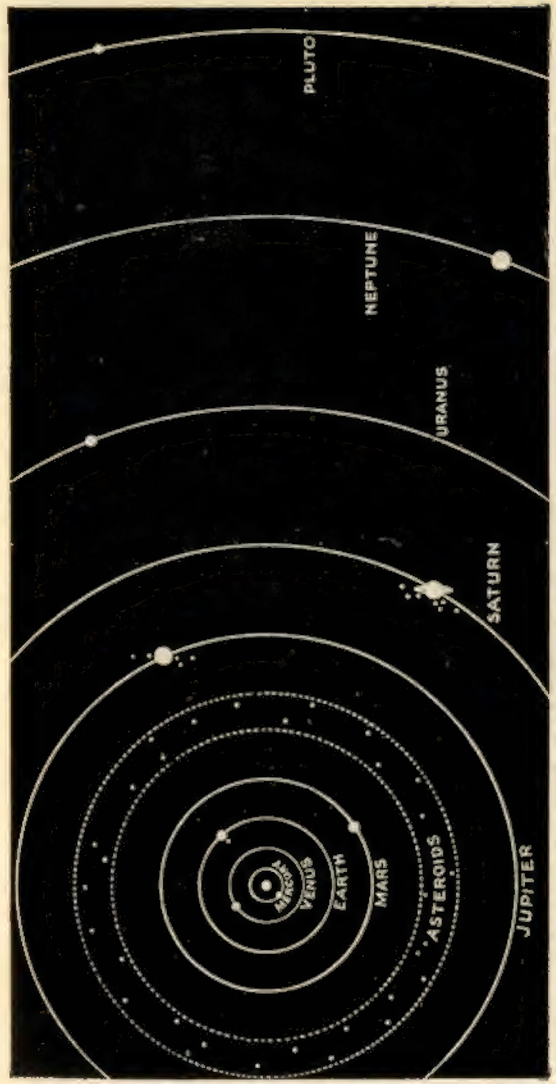

PLATE XII.—DIAGRAM OF THE SOLAR SYSTEM, SHOWING APPROXIMATE POSITIONS OF THE ORBITS OF THE PLANETS.

PLATE XIII.—TWO VIEWS OF VENUS.
(*From drawings by Ellison Hawks.*)

Sun's rays, but we have a proof that this is so in what has been said in an earlier chapter about Earth-shine.

Mars was called by the people of old the "Fiery Planet," because it shines with a ruddy light. Its name comes from the Greek *Ares*, "god of war," and it was the symbol of war to the ancients, for its ruddy colour reminded them of the blood of battle. Mars has been attentively observed with the telescope for over three hundred years. Galileo was the first to turn his attention to the planet, but he did not discover anything of importance. It was not until later that interesting markings were seen on its surface. To-day more is known about Mars than about any other planet in the Sun's family.

Looking at Mars through a telescope, we find that it is not surrounded by dazzling bright clouds as Venus is. This enables us to see markings on its surface, such as are shown in Plate XIV. It was at one time supposed that these dark markings were seas, and that the light markings were land. It is now believed that the dark markings are great plains covered by vegetation, and that the light markings are sandy wastes. There do not appear to be any seas on Mars, and this seems a great pity, for if there are any inhabitants there they will never be able to enjoy a holiday at the seaside!

Perhaps the most interesting objects on Mars are the brilliant white patches to be seen around the Poles. We all know that at the North and South Poles of the Earth there are great areas of ice and snow that form the Arctic and Antarctic regions. If we could stand on the Moon and look back at the Earth, these

polar regions would appear as white patches exactly as we see those on Mars. There are both north and south polar regions on Mars, but in Plate XIV. only one is seen, the other being hidden by the bottom part of the planet.

As summer advances on the Earth, the ice and snow of the polar regions partly melt. You will sometimes read of icebergs being seen from ships in the Atlantic Ocean. These icebergs are really portions that have broken away from the vast ice-fields at the North Pole and have been carried southward by ocean currents. Now, Mars has seasons just as we have, and during the Martian summer we can see its polar cap growing smaller and smaller as the ice and snow melts. Sometimes we can actually see the water from the melting snow and ice in the form of a dark ring around the polar cap. With our telescope we can follow the succession of summer and winter on the planet. As the winters approach, snow accumulates first at the North Pole and then at the South. When it is winter in the northern hemisphere of Mars it is summer south of the Martian equator, exactly as is the case on the Earth. There, too, the rigours of winter are softened by the spring, whilst autumn heralds the approach of another winter. Throughout all these seasonal changes the areas of vegetation change in colour from the verdant green of springtime to the russet brown of autumn. I am sure you will agree that it is a fascinating study to be able to watch all these changes taking place in another world millions of miles distant.

Although we thus see that Mars is a world something

like our own Earth, with its polar caps and its seasons, there are several differences between the two planets. For one thing, there do not appear to be any mountains on Mars. Another difference is that whereas the Earth has an abundance of clouds, Mars has practically none. The sky is nearly always clear, except for light mists that disperse when they encounter the warm sunshine. There must be continually fine weather on Mars, for if there are no clouds there cannot be any rain. Whether any people exist there to enjoy this beautiful state of things we do not know, but some astronomers are convinced that there is life of some kind on Mars. Some faint markings are said by some to be canals cut by the Martians. These, they say, bring the water from the melting polar caps to the desert areas, and make it possible for the Martians to cultivate vegetation, which in the absence of rain would certainly not otherwise grow. Whether or not this fascinating theory is correct we do not know. Mars is such a vast distance away from the Earth that even large telescopes show some observers little more than the different-coloured markings on the surface of the planet.

Our Earth has only one satellite, but Mars has two, both of which were discovered in 1877. They are called Deimos and Phobos, the names in ancient legend of the two horses that drew the chariot of Mars, the god of war. They are very tiny, for Phobos is only ten miles in diameter, and Deimos only about five.

Outside the orbit of Mars are a host of tiny planets called the asteroids (Plate XII.). It is supposed that they were once part of a great ring of matter, formed at

a period when the Solar System was but a gaseous mass. Another theory is that they may be the fragments of a planet that has been blown to pieces by some great catastrophe in the remote past. There are nearly two thousand of these tiny planets, the largest of which would stretch only from London to Edinburgh. Most of them are so small that probably they do not exceed ten miles in diameter. Although of but little interest in the telescope, one or two of these little planets have been of great assistance in helping to determine more accurately the distance of the Sun.

	EARTH.	MARS.
Diameter	7,920 miles	4,215 miles
Mean distance from Sun .	92,870,000 miles	141,500,000 miles
Revolves around Sun in .	365 days	687 days
Rotates on axis in. . .	23 h. 56 m.	24 h. 37 m.

PLATE XIV.—THE PLANET MARS, SHOWING DARK MARKINGS, "CANALS," AND THE SOUTH POLAR CAP.
(From a painting by Ellison Hawks.)

PLATE XV.—JUPITER AND ITS CLOUD BELTS.
(From a painting by Ellison Hawks.)

CHAPTER VIII

JUPITER, THE GIANT PLANET

BEYOND the asteroids lies the orbit of Jupiter, often called the "Giant Planet," for it is the biggest planet of the Sun's family. Indeed, Jupiter would be larger than all the other planets rolled into one. If placed in a row, Mercury, Venus, the Earth, and Mars would only represent about a quarter of Jupiter's diameter. If we placed Jupiter in one pan of a great pair of scales, we should have to put no less than 317 planets as heavy as our Earth into the other pan before we could weigh it down.

Through the telescope we see that Jupiter appears as a huge globe of clouds. (Plate XV.) You will remember that when writing of Venus I mentioned the fact that it is probably surrounded by a mass of cloud. Whilst the clouds of Venus do not show any definite formation or any pronounced markings, those of Jupiter always range themselves in great belts across the planet in lines that lie parallel to Jupiter's equator. They present a great variety of detail as the planet rotates on its axis, and often resemble the cumulus, or "snow-mountain," clouds of our own skies. Many are delicately tinted with colours that range from bright yellow to

reddish-brown and chocolate, with occasional faint blue and olive green.

Towards the centre of Plate XV. you will see a kind of spoon-shaped marking. Some years ago, in the centre of this peculiarly shaped feature, a curious object was to be seen—the Great Red Spot. It was of a bright red colour, but during recent years its colour has gradually faded, and it is now only occasionally to be seen as a faint marking. In spite of its name, this object is far from being a "spot" actually, for its length is 26,000 miles (fully three times the diameter of the Earth), and its breadth 7,000 miles. It is believed that the Great Red Spot was observed as long ago as 1665. Certainly it has been seen for more than fifty years, and during this time it has been a most interesting object to astronomers. Sir Frank Dyson, the late Astronomer Royal, thought the Spot might be in the nature of an enormous floating island that reared its crest above the clouds of Jupiter. Exactly what it is, however, no one can tell, and although many theories have been put forward, none of them has been generally accepted as entirely satisfactory.

You will notice that Jupiter is slightly oval in shape, and for this reason. As we have seen, the planet is a very big world, and it turns on its axis very quickly. The Earth rotates once in twenty-four hours, but Jupiter requires only a little less than ten hours. As it is a much bigger world than the Earth, it has therefore to turn at a very much greater speed, and it is this that makes the planet bulge at the equator.

Perhaps the most interesting feature about Jupiter is

its satellites. Whereas the Earth has only one Moon, and Mars two, Jupiter has no fewer than nine known to us, and probably there are some as yet undiscovered. Can you imagine the remarkable sight of seeing nine moons in the sky at one time? Although four of the largest satellites can be seen with even a small telescope (Plate XVI.), the other five are very tiny and are difficult to see, for Jupiter is even farther away from us than Mars. Exactly as the Moon travels around the Earth, so, too, do Jupiter's satellites travel around it. Through a telescope we can see them slowly moving hour by hour. The sight is most beautiful, for it is almost like looking at a model of the Sun's family, with Jupiter for the Sun and the satellites for planets.

Most of you will have read of the famous astronomer Galileo, who lived in Florence early in the seventeenth century. Galileo was one of the first to use a telescope, and one night he directed his instrument to Jupiter. There he saw this wonderful sight of the satellites travelling around the great planet, and he called his friends to look with him. But at that time people really thought that the Earth was the centre of everything—they even believed that the Sun travelled round the Earth, instead of the Earth round the Sun! Galileo had tried to show that the Earth was not the centre of all things, and that there were other worlds as well as the Earth travelling around the Sun. The people, however, looked upon him as a magician, and would not believe him. In consequence he experienced many trials and hardships. When he saw Jupiter, and four large satellites travelling around it, he again put forward the theory

that the Earth travels around the Sun, and he pointed to Jupiter as an illustration of how this might be.

At first people would not believe him, and said that there must be something the matter with his telescope, so he asked them to look for themselves. Some looked and were forced to admit that there was a system of moons travelling round the great planet, but they then said that Galileo had bewitched either the telescope or their eyes! They brought forward every objection they could think of in order to try to make themselves still believe that the Earth was the centre of all things. After some time, however, other learned men took up the subject, and those who had thought that the Earth was at the centre of everything had to admit they were wrong. It was clearly shown that the Earth did travel round the Sun, and Jupiter and his system helped to prove it. It is very interesting to be able to look through a telescope and see these same satellites travelling around Jupiter in an exactly similar manner as in the far-off days when Galileo saw them.

Jupiter's satellites constantly present us with a varied programme. Sometimes they move between the Sun and the planet. Such an occurrence is known as a transit, as has already been mentioned (see page 39). As they pass between Jupiter and the Sun, the satellites throw tiny round shadows on the planet. Then we see both the satellites and their shadows against the background of the cloud belts. At other times the satellites are eclipsed by passing into the great shadow cast in space by Jupiter, exactly as our Moon is eclipsed by passing into the Earth's shadow. When the satellites pass

PLATE XVI.—THE GIANT PLANET JUPITER, SHOWING THE FOUR PRINCIPAL SATELLITES.
(From a drawing by Ellison Hawks.)

behind the planet they are said to be occulted, from a Latin word meaning " to hide." If ever you have the opportunity of looking through a telescope be sure to ask the astronomer to show you Jupiter, if it is to be seen. You will be delighted to watch the four satellites, and to see the cloud belts that lie across the planet's disc.

JUPITER

Diameter	88,640 miles
Mean distance from Sun . .	483,200,000 miles
Revolves around Sun in . . .	$11\frac{3}{4}$ years
Rotates on axis in	(about) 9 h. 55 m.

CHAPTER IX

SATURN, THE RINGED PLANET

I AM now to tell you of what is perhaps the most beautiful object to be seen through a telescope. This is the planet Saturn, the orbit of which lies beyond that of Jupiter. To the naked eye the planet looks like a bright star, and there is no hint of the wonderful object that is revealed by the telescope. Saturn differs from all other planets of the Sun's family, however, for the globe of the planet is encircled by a beautiful series of rings. These rings, which can be seen only through a telescope, look something like the outer rim of a dinner-plate held edgeways. You will gain some idea of what I mean from Plate XVII. Seen from Saturn itself, the rings would provide a marvellous spectacle. At night the whole sky would be illuminated by this wonderful arch of light, with which there is nothing to compare anywhere in the heavens.

The rings do not touch the planet anywhere. How a planet could be surrounded by an object that has no means of support proved a complete mystery to the early astronomers. The mystery remained unsolved until 1856, when it was suggested that Saturn's rings consist of a swarm of small bodies each travelling in its own path around the planet. They are so tiny, and

so far away from us, however, that even with our greatest telescopes we cannot see them separately, and so they appear as continuous rings of light surrounding the planet. We must here point out that the rings do not shine by means of their own light, but reflect to us the light of the Sun.

As will be seen, there are dark rings as well as bright rings. These dark rings are spaces in the bright rings, from which the small bodies are missing, thus making divisions in the bright ring. The two chief bright rings are called the Outer and Inner rings, and you will notice that the former ring is not quite as bright as the latter ring, and that a well-marked division separates them. This division is called the Cassini Division, because in 1675 an astronomer of that name was the first to notice it. Between the Inner ring and the planet you will see a delicate ring that is neither bright nor dark. Indeed, it looks as though it were composed of gauze, and for this reason it is known as the Crape Ring. You will notice that the edge of the globe of Saturn is clearly visible through the Crape Ring. From tip to tip the ring system measures some 170,000 miles, but the average thickness of the rings is only about 10 miles.

Saturn's rings are seen under different aspects during a period of fifteen years, due to the fact that Saturn tilts towards us at certain periods. Consequently, at one time we are looking at the rings from above, whilst at another we appear to be looking at them from below, and between the two extremes we see them edgeways. When seen edgeways, the rings do not present

the beautiful appearance shown in Plate XVII., for then they are but a thin line extending for a short distance on each side of the planet. You will be able to understand how their aspect differs by holding a dinner-plate at arm's length, and by gradually raising or lowering the front edge until it seems only to be a thin line in front of you.

When Galileo turned his telescope to Saturn, some three hundred years ago, he was much puzzled by these changes of the rings. His telescope was only of low power, and it did not show objects sharply and clearly. It was for this reason that he could not see the true nature of the rings, and they were most mystifying to him. To him it seemed as though Saturn was composed of three bodies, of which the centre one looked the largest. He wrote: "I have observed with great admiration that Saturn is not a single star, but three together, which, as it were, touch each other . . . the middle being much larger than the side ones." He goes on to say that "Saturn has an oblong appearance and is somewhat like an olive." Galileo died without having solved the mystery of the rings, and it was not until forty years later that a clever Dutch astronomer, named Huyghens, saw the rings of Saturn in their true form.

The globe of Saturn is surrounded by cloud belts, something similar to those that encircle Jupiter. As seen through the telescope the details of Saturn's clouds are not nearly so distinct, however, as those of the Giant Planet, probably because Saturn is so much farther away.

The farther away from the Sun a planet is situated, the

longer it takes it to travel around its orbit. The Earth travels round the Sun once a year. Jupiter, being farther, takes twelve of our years to make one revolution. Saturn, at an even greater distance, requires nearly thirty years to make one journey around the Sun. Long though this may seem, we shall presently see that there are members of the Sun's family that require even longer periods in which to complete their journey.

Saturn has no fewer than ten satellites. Just imagine what a marvellous sight it would be to see ten moons in our evening sky, to say nothing of the extraordinary ring system! If you are fortunate enough to be able to see Saturn through a telescope you will never forget the sight—but you must not expect to see all the satellites, for they are very small bodies.

SATURN

Diameter	74,100 miles
Mean distance from Sun . .	885,900,000 miles
Revolves around Sun in . . .	29½ years
Rotates on axis in	(about) 10 h. 14 m.

CHAPTER X

URANUS, HERSCHEL'S PLANET

ACCORDING to the ancients, Saturn was the outermost planet of the Sun's family, but we now know that beyond Saturn there are three other planets—Uranus (pronounced "you-ran-us"), Neptune, and Pluto. These three members of the Sun's family are so far away that we know very little about their appearance. Even in a large telescope they seem very small indeed; and though it has been supposed that both Uranus and Neptune have cloud belts resembling those of Jupiter, we cannot state this with certainty. A very interesting thing about Uranus is the way in which it was discovered. The planet is so far away that it is almost invisible to the naked eye, and so Uranus was unknown before telescopes were invented.

One of the greatest astronomers who ever lived was William Herschel. Before he became an astronomer he was a soldier in the Hanoverian army, and one night, just before a great battle, he, together with some other soldiers, had to sleep as best he could in a wet and muddy ditch. Herschel did not like this at all, and so he decided to leave the army, and in 1757 he came to England. He studied music diligently, and after a time became the organist of the Octagon Chapel at Bath.

He was very studious, and every minute he could spare was devoted to his music. Intending to master his subject thoroughly, he commenced to study mathematics, which is the science of numbers and space. It was in this manner that he was brought into touch with astronomy.

Although Herschel had often admired the stars, he probably never thought much about them. Once his interest had been aroused, however, he began to give much time to a study of the heavens. Soon he was so thrilled with his new hobby that he began to devote even more time to astronomy than to music, and his organ and his music pupils now took second place. Next he commenced to make telescopes—small ones at first, and then larger ones—and with them he explored the wonders of the heavens. At this time no one, and least of all Herschel himself, could have imagined that he was shortly to become famous throughout the world.

And so the months passed by, Herschel teaching his music pupils in the daytime and conducting concerts at night. After the work of the day was over, he sat up far into the night. If the night was fine he would observe, but if the clouds prevented this, he would be at work on some telescope. It is said that he would even run out during a concert interval in order to do a little more work at the telescope he happened to be making. He had one companion in his long night watches, and this was his devoted sister Caroline. She would sit in the little shed near his telescope, patiently making notes of the observations he made at the instrument. One hardly knows to whom there is more credit

due—to William for his persevering and scientific mind, or to Caroline for her painstaking and accurate notes of her brother's observations.

There came a time when Herschel decided he must have a very large telescope. He could not afford to buy one of the size he wanted, so the only solution to the difficulty was to make one for himself. He set himself to work, and his home was transformed into a work-place. The drawing-room he used as a carpenter's shop, and the best bedroom was furnished with benches. Tools of all descriptions were scattered about. So interested was he in the task that he would rush home after conducting a brilliant concert in Bath, to commence work without even waiting to take off his lace collar and cuffs, which were the fashion in those days.

After much labour the great telescope was finished in 1779, and Herschel set himself to observe all stars down to a certain degree of brightness. It was whilst carrying out these observations in the constellation of the Twins that he came across what appeared to him to be a strange object. In a telescope the stars seem to be only points of light, but the planets appear as round discs—like little worlds, in fact. This strange object, which Herschel found on the night of 13th March 1781, did not resemble a star—indeed it looked more like a planet. After several nights of watching, he found that it had moved among the stars. Not daring to suppose that he had found a new planet, Herschel announced to the world that he had discovered a comet, and he sent his observations to some mathematicians. It was not long before they made it known far and

PLATE XVII.—SATURN AND ITS RINGS.
(From a drawing by Ellison Hawks.)

wide that the object Herschel had discovered was not a comet, but was indeed a new planet. The seventh planet received the name of Uranus, which was very appropriate, for in ancient mythology this was the name of Saturn's father.

Then did Herschel become famous, and the honours he deserved were accorded him. The king, George III., was so pleased with him that he made him Astronomer Royal. This appointment enabled him to leave his music and to devote all his attention to astronomy. Afterwards he was knighted, and continued his observations up to the time of his death, being always accompanied by his faithful sister Caroline.

Uranus is 32,400 miles in diameter, and is nineteen times as far from the Sun as the Earth. It takes over eighty-four years to complete one circuit of its orbit. It has four satellites, named Titania, Oberon, Ariel, and Umbriel. The first two, the brightest, were discovered by Herschel in 1787, but the other two were not discovered until 1851.

	URANUS.	NEPTUNE.
Diameter	(about) 32,400 miles	31,000 miles
Mean distance from Sun	1,782,300,000 miles	2,792,700,000 miles
Revolves around Sun in	84 years	164 years
Rotates on axis in. .	$10\frac{3}{4}$ h.	(believed to be) 15 h.

CHAPTER XI

NEPTUNE AND PLUTO, THE FARTHEST PLANETS

IF Sir William Herschel's discovery of Uranus was wonderful, so too was the finding of Neptune, which until 1930 was believed to be the outermost planet of the Sun's family.

When the mathematicians had calculated the path of Uranus, they were able to predict the place in the sky where the planet should be, thus enabling the astronomers to direct their telescopes to the spot to observe it. By 1825 it was evident that there must be something wrong with the calculations, however, for Uranus was not always to be found at the exact place the predictions said it should be. The figures were gone over time after time, and although no mistakes were found in the work, Uranus was still not where it should have been, according to the men of figures. Sometimes the planet was a little late in reaching a certain position in the heavens, or at other times it was too soon. This went on for a considerable time until at last two clever mathematicians—J. C. Adams, an undergraduate at Cambridge, and Urbain Le Verrier, who later became Director of the Paris Observatory—set themselves the task of investigating the matter.

It was thought that perhaps the trouble was due to an undiscovered planet beyond Uranus; and that this other planet was acting like a great magnet on Uranus, sometimes pulling it back and making it late, and at other times pulling it forward and making it too early. The question that the two mathematicians had to answer was: Is there really another planet; and if so, how large is it, and—more important—where is it?

Now you will easily understand that, even with a planet that is well known, to calculate its exact place in the sky must indeed be very difficult. But how much more so must be the finding of the position of a planet that has never been seen and about which nothing is known! This was the formidable task that Adams and Le Verrier set themselves to work out, and it was a very curious thing that neither knew that the other had undertaken the calculation. It was even more extraordinary that they both obtained almost the same results when their calculations were finished. It was not until Le Verrier came to make his results known to the world that they found they had both been engaged in trying to solve the same problem, unknown to each other. As it happened, Adams had finished first, and he sent his results to Greenwich Observatory, but the Astronomer Royal of that day did not think much about the matter, and did not seem to understand what a long time had been necessary to complete the calculations. When he received Adams's result, which gave the position in the sky of the supposed new planet, instead of immediately setting his assistants to work to look at the place

indicated, he put the papers in a drawer and forgot all about them!

Soon after this, however, M. Le Verrier sent his calculations to Dr. Galle, the Director of the Berlin Observatory. Galle realized that Le Verrier's work was important and that the matter must be looked into. He immediately began to observe the stars in that part of the sky where the French mathematician indicated the new planet might be found. On the night of 23rd September 1846, Galle found a strange object among the stars. Soon afterwards it was proved that the object was indeed another planet, and to it the name Neptune was given.

Naturally there was great rejoicing when the discovery of Neptune became known, and of course Le Verrier was delighted that his work should have been so speedily rewarded. But what of Adams's calculations? He had done the work and arrived at the same result, yet had not received any credit for his labours, for his working papers had been lying forgotten at Greenwich Observatory. The news of Le Verrier's triumph reminded the Astronomer Royal of the results that were still lying in his drawer. Examining them, he saw at once that Adams's result was practically the same as Le Verrier's. He hastened to make known to the world the circumstance of the calculations having been sent to him some months before Le Verrier had published his figures. Although at first Le Verrier was not at all pleased with this news, later he came to see that there was credit due to the English mathematician, and it was determined that the two should share the

glory of Neptune's discovery. The discovery was a notable achievement for mathematics, and one that will always be remembered in the history of astronomy.

Neptune cannot be seen with the naked eye, but a pair of good field-glasses enables it to be seen as a faint star. It is nearly four times as large as the Earth, and has at least one satellite. To us a year often seems a long time, but what should we feel if we lived on Neptune, for it takes over 164 years to make one revolution of its orbit. Neptune is about thirty times as far distant from the Sun as is the Earth, and at this distance the Sun will appear merely as a bright star.

More recently history has repeated itself, and beyond Neptune has been discovered another planet to which the name Pluto has been given. Even after taking into account the attraction of Neptune, Uranus was still not where it should have been in the sky, according to observers who had been carefully watching the planet and noting its position. Astronomers suspected that the discrepancies might be due to yet another planet, and the late Professor Lowell undertook to calculate the probable position of this supposed ninth planet. It was not until fifteen years after he had published the results of his work that the new planet was discovered (in January 1930), and it is a tribute to the mathematician that it was found near the place where Professor Lowell predicted.

Pluto is nearly forty times as far from the Sun as is the Earth. Because of this, and the fact that it is comparatively small, it can only be seen with a powerful telescope, and we do not yet know much about it.

CHAPTER XII

COMETS

WE are now to learn something about those wondrous objects called comets, a word that comes from the Greek *kometes*, "long-haired." When seen at night, a comet certainly does look like a strand of very fine silvery hair hanging against the dark sky. Although there are on an average as many as five comets in a year, these are mostly small ones that are only to be seen through a telescope. Sometimes, however, comets are bright enough to be seen with the naked eye, and occasionally we are favoured by the visit of a really large comet.

If you read the poems of Oliver Wendell Holmes you will find that he speaks of a comet as "the spectre of the skies." It is popularly supposed that chairs and tables may be seen through a ghost's body, but whether this is so or not I am unable to say, for ghosts are difficult things to experiment with. As the famous Mrs. Beeton said about preparing jugged hare, it is first necessary to catch the hare—and no one has yet succeeded in catching a ghost! However, whatever may be the case, it is certain that stars can be seen shining through a comet's tail, and this is probably one reason why comets have been called "spectres."

A comet may be said to be composed of two parts—the head or nucleus, which is really the comet itself, and the tail. People who know little about astronomy think that the tail is by far the more important part about a comet. This is not so, however, although it is true that a fine tail makes a comet look far more imposing in the sky.

Comets travel around the Sun just as planets do, and although they do not always follow the same kind of orbit as a planet, they obey the same laws, and they also are ruled over by the Sun. Some comets complete a circuit of their orbit in a few years—Encke's Comet takes only about four and a half years—but others take longer, some requiring many thousands of years. A most beautiful comet was discovered by Donati, an Italian astronomer, in the autumn of 1858. Although this is a long time ago, people have told me that they can distinctly remember the comet because it was such a brilliant object in the sky—so bright, indeed, that it considerably frightened many people. It remained visible to the naked eye for three months, and for nine months longer in the telescope. Unfortunately none of us will see this comet, for it will not return to the Sun for nearly two thousand years!

There was a most interesting comet in November 1908, called the Morehouse Comet, photographs of which are to be seen on Plates XVIII. and XIX. Although it was a faint object, and only visible through a telescope, it was remarkably interesting because of the curious behaviour of its tails, which underwent many changes. On a certain night it had one long tail, but on another

evening it suddenly developed no fewer than six tails. On another night, later still, I was surprised to find that it had no tail at all! In this mysterious way comets can puzzle astronomers, and baffle all attempts to find out of what they are made or whence they come.

The two photographs on Plates XVIII. and XIX. were taken on different dates. In the former you will notice gaseous spikes shooting out from the nucleus, and forming small tails, behind the comet. The great tail itself streams far and away behind the nucleus, and seems to twist and curl as smoke from a chimney does on a windy day. In the other photograph the appearance is quite different, for the tails are now spread out fanwise. The little white streaks you see around the comet in these photographs are not faults, but stars in front of which the comet is passing as it travels in the sky.

We do not know what a comet really is, for there have not been many bright ones to examine since our large observatories were established. From what has been learned, however, it seems probable that they are largely composed of gaseous matter. To express it in another way, they may be simply clouds of gas that in some manner are held together as they travel around the Sun.

When a comet is first seen through a telescope it resembles a small misty star or faint patch of light. As it draws nearer to the Sun its brightness increases, until it is seen in all its glory, and if it is a large comet it will then be a magnificent object in the sky. After that it fades away, until it is once more a misty patch of light, becoming fainter and fainter until it is lost in

PLATE XVIII.—THE MOREHOUSE COMET, SHOWING STARS SHINING THROUGH ITS TAIL.

(*Photograph by Dr. Max Wolf.*)

PLATE XIX.—THE MOREHOUSE COMET, SHOWING SEVERAL TAILS.

(Photograph, Royal Observatory, Greenwich.)

PLATE XX.—THE DAYLIGHT COMET, 21ST JANUARY 1910.

(From a painting by Ellison Hawks.)

the depths of space and cannot be seen even with the largest telescope. There is one thing from which the comet cannot escape, however, and that is the unfailing pen of the mathematician. Although a comet may be invisible for years, the mathematicians can calculate exactly where it is in the depths of space, and they can also tell when it will return and in what part of the sky.

Comets do not always come back when expected, however, for sometimes they stray away and are lost. In 1770 Lexell's Comet disappeared from view, and as far as we know it has not been seen since, nor has Di Vico's Comet of 1844. Then again, a comet may appear in quite a different form from that in which it was seen on a previous visit. There was a comet in 1826, known as Biela's, because of its discovery by Wilhelm von Biela, an Austrian soldier. This comet required a little over six years to traverse its path around the Sun, and in 1845 it actually split up into two, both parts travelling along together, like two friends out for a walk! The next time they came back, which was in 1852, the two portions were still travelling along, but after that they were lost, and they have never been seen since. These facts show us that comets, although governed by the same laws as the planets, are unreliable and may do all kinds of unexpected things.

One of the most wonderful comets of recent times appeared during the month of January 1910. It was called the "Miner's Comet" by some, while others named it the "Daylight Comet" (Plate XX.). As a rule astronomers do not give names to a comet, but

simply give it a number, or rather a letter, which is placed after the year in which the comet is discovered. For instance, this Daylight Comet was the first comet to be discovered in 1910, and consequently it was known as " Comet 1910 *a*." The second comet to be discovered in the year was called " Comet 1910 *b*," and so on. The Daylight Comet was indeed a beautiful sight, and I shall never forget the first time I saw it. The Sun had just set, and the sky was a beautiful primrose-yellow ; a low bank of purple cloud hung near the horizon, while high up to the left was the planet Venus, shining with great brilliance. Somewhat below and to the right of Venus was the great comet itself, looking like a sheaf of golden fire, its beautifully curved tail stretching across the sky for a considerable distance.

Although the mathematicians are able to tell us a great deal about the comets, and when to expect them, they can only give us this information of comets that have actually been observed. Sometimes unknown comets appear, and these are indeed " surprise comets," for they come to us quite unexpectedly. The Daylight Comet was one of this class, for it was discovered just after sunrise on the morning of 13th January 1910, by some miners in the Transvaal, South Africa. Seeing the strange-looking object in the eastern sky, they telephoned to the nearest observatory, and from here was spread the news of the wonderful discovery. A few days later the comet was seen from several parts of England, first by those who were on the watch for it and knew where to look, and afterwards by thousands of other people.

After a few days of great brilliance the comet gradually faded away, until it became but a faint speck in the telescope. It had lost its beautiful tail, and was travelling away into the space from which it will never return.

CHAPTER XIII

HALLEY'S COMET

ONE of the most famous comets is that named after Edmund Halley, who was born in 1656, and was educated first at St. Paul's School, London, and later at Queen's College, Oxford. Halley was passionately fond of astronomy, and in later years held the appointment of Astronomer Royal. He was a great friend of Sir Isaac Newton, who had not only explained the movements of the planets, but also suggested that comets revolve around the Sun. Realizing the importance of his friend's suggestion, Halley determined to investigate the problem. He commenced his task by mapping the paths of twenty-four comets that had appeared between 1337 and 1698. In doing this he noticed that three of these comets followed paths that were very similar. Indeed, it seemed possible that they were not three different comets, but rather three appearances of the same comet. Halley noticed that this particular comet seemed to appear once in about every seventy-five years, and he took the daring step of predicting its return in the year 1758. Unfortunately he died before that year came, but true to his prediction the comet came back. It was named Halley's Comet as a tribute to the work

that he had done in connection with comets in general, and with this one in particular.

As Halley's Comet comes to the Sun every seventy-five years, and as the Earth is comparatively near to the Sun, it follows that the comet will be visible every seventy-five years. It is only natural to suppose that it would have been seen on many occasions before Halley's time, and by looking up records of comets we can trace this comet for hundreds of years—indeed, up to a time long before the birth of Christ. Some of the records of the comet were made on parchment, but the earlier ones were on clay tablets such as have been found in the land of Ancient Egypt.

Of all the records, those of the Chinese have been the most useful in tracing back Halley's Comet. The Chinese thought that the constellations represented countries on the Earth, and imagined that they could tell what was about to happen to the nations of the world by watching the stars in the sky. Of course, when a strange object, such as a comet, appeared among the "kingdoms of the sky," it was a cause of great excitement. It was regarded as a sign that an ambassador was about to visit that particular country on Earth that corresponded to the constellations through which the comet passed. Comets were therefore looked upon as very important objects by the Chinese, and very careful records were kept, not only of their appearance, but also—what is more important still—of the stars near which the comets passed. The Chinese thought that by keeping these accounts they would be able to predict happenings on the Earth, little thinking that these

records would be most useful to twentieth-century astronomers in tracing former appearances of Halley's Comet.

In olden days people were very frightened when a comet made its appearance in the sky, and associated all manner of curious happenings with it. In 371 B.C. a bright comet appeared and was blamed for a terrible earthquake that caused the two towns of Anchaia to be swallowed up by the sea. Shakespeare voiced the popular superstition when in his *Julius Cæsar* he wrote those famous lines:

When beggars die there are no comets seen,
The heavens themselves blaze forth the death of princes."

The Romans thought that a great comet that appeared in 43 B.C. was a chariot sent by the gods to carry away the soul of Julius Cæsar, who had been assassinated shortly before. Pliny, in his wonderful book on Natural History, tells us that "a comet is ordinarily a very fearful star. It announces no small effusion of blood." William of Malmesbury, writing in the year 1060, after mentioning the death by poison of Henry, King of France, says: "Soon after a comet—denoting, as they say, change of Kingdoms—appeared, trailing its extended and fiery train along the sky."

We should suppose that in modern times superstition of this kind would have been given up, but there are still some people who seem to believe in it. When the Daylight Comet was visible in our evening skies in 1910, some said that it was the cause of great floods that were taking place in Paris. These people did not know that

at the same time that there were floods in Paris there was also a "water famine" in Egypt, and that the Arabs were blaming the comet for causing their water supply to dry up! Other people, who thought that the comet was a sign that the world was coming to an end, must have been surprised to find that life went on as usual whilst the comet was visible and also after it had disappeared!

At Bayeux, a town in Normandy, there is a most interesting tapestry that tradition says was worked by Queen Matilda, William the Conqueror's wife. This tapestry consists of a strip of linen some two hundred feet in length, and is worked in worsted in seven colours. It has been very useful to historians, for its pictures have shown us many of the manners and customs of those days, and they have taught us many other things that would otherwise have remained unknown. One of these pictures (shown on Plate XXI.) shows the people watching a comet in the sky. There is inscribed over it the words: "ISTIMIRANT STELLA," which means "These people wonder at the star." It has been proved that the comet shown in this picture is Halley's Comet, as seen on its 1066 return, a date you will remember as being famous for the invasion of England by the Normans.

When the people saw the great comet in the sky they were very much afraid, and you will see, from the expression on their faces, that they seem to be expecting something awful to happen. William himself was not afraid of the comet, and told his frightened soldiers that the comet was a sign that a kingdom wanted a king.

Thus reassured, the soldiers set out in the ships for England, ready to help their leader to win the kingdom. As we know, the Normans defeated the English, Harold was slain at the Battle of Senlac, near Hastings, and William was made king. It was only natural that the English people should then feel quite convinced that these misfortunes were caused by the comet, for dreadful things had been predicted from its appearance. One writer goes so far as to say that if the comet had not appeared and frightened the English, William might never have been "the Conqueror!"

Halley's Comet last appeared in 1910, so it will next be seen in 1986. Some of you who read these lines may live to see it then. If you do it will be interesting for you to remember, as I did in 1910, that the comet you are looking at is the same comet that was seen by William the Conqueror and by the English people before the Normans invaded our shores.

PLATE XXI.—HALLEY'S COMET IN 1066, AS DEPICTED ON THE BAYEUX TAPESTRY.
(*From a painting by Ellison Hawks.*)

PLATE XXII.—A METEOR FLASHES ACROSS THE SKY.
(From a painting by Ellison Hawks.)

CHAPTER XIV

METEORS, THE GREEN FLASH, AND THE AURORA

OFTEN on a dark night, when the stars are shining with all their brilliance, there suddenly dashes across the sky a streak of gorgeous light (Plate XXII.), which disappears as silently as it came. When these objects are called "shooting stars," or "falling stars," they are wrongly named, for they are not really stars at all, though they certainly do look like them. They are more correctly known as meteors, from the Greek *meteoros*, "raised on high." Their origin is not definitely known, but they are believed to be the débris of comets that have broken up, for they travel in swarms along regular orbits around the Sun.

We do not become aware of the actual presence of a meteor until it enters our atmosphere and becomes intensely heated by the resistance of the air. You know that when you rub a piece of india-rubber on paper, the rubber becomes quite hot, and the harder you rub the hotter does it become. This heat is generated by friction, and it is in a somewhat similar manner that the meteor becomes heated. In rushing through the Earth's atmosphere at a speed of over thirty miles a second, each particle of air rubs against the meteoric

body, the meteor becomes incandescent, and we see it as a "shooting star."

When a meteor is of considerable size it may actually reach the ground before it has all been dissipated. In a few cases we are able to find these bodies, which are then called meteorites. One such fell on 20th April 1876. On that day, at about 3.30 in the afternoon, the people who lived in and around the village of Rowton, in Shropshire, heard a great rumbling noise, followed by a loud explosion. A farmer found that a huge meteorite, weighing about 7¾ pounds, had fallen in one of his fields. It was quite warm when he first saw it, and if it had fallen at night it would have provided a marvellous display of "celestial fireworks." If you visit the Science Museum at South Kensington you will be able to see large numbers of these meteorites, including the one that fell at Rowton. Some are composed almost entirely of iron, others of iron and stone, and others almost entirely of stone. They are of all sizes, from that of a grain of sand to a huge mass weighing many tons. The largest known meteorite was found by Admiral Peary, the polar explorer, at Melville Bay, Greenland. It weighs 36½ tons, and is now in the American Museum of Natural History, New York.

As meteors travel in regular orbits, we are able to expect them at certain times of the year when the Earth crosses their paths. There are many of these dates throughout the year, such as 24th March, 20th to 22nd April, 10th to 12th August, and 13th to 15th November each year. If you look out on these nights, and if the sky be clear, you are certain to see some meteors. They will not all come at once, but first one and then another a few minutes later, and although most of them will be small, every now and then you may be rewarded by a particularly bright one. You will notice, too, that they differ in colour, some being white, others blue, yellow, or red. Some travel across the sky very quickly, whilst others travel comparatively slowly. Often they leave trails behind them, which may last for a few seconds, or perhaps for several minutes. On 22nd February 1909 there was a very bright one, which some people said seemed to be as large as the full Moon. It left behind it a trail that remained in the sky for four or five hours after the meteor itself had vanished.

Sometimes, however, when great displays of meteors are expected they do not take place. On 13th November 1899 a considerable shower of shooting stars was expected, and a great crowd of people waited for many hours. Although it was a clear night, nothing happened, but still the people waited. When it was long past midnight, some university students, who intended to have some fun, set off a great flight of sky-rockets—the kind that burst and send out showers of coloured stars. When the expectant people saw all these beautiful "firework stars," they cried, "Look! Look! There are the shooting stars! Aren't they marvellous!" Then they went home to bed quite satisfied to think that they had seen the real shooting stars. I do not believe they know to this day that what they saw on that night were only fireworks set off by the university students!

Let us now turn to another subject—the Green Flash,

which is sometimes seen as the Sun is disappearing over the distant horizon, when its tip turns to a beautiful blue-green colour. This is due to an atmospheric effect, for near the horizon the atmosphere is denser than the air above. No doubt you will be able to view the Flash some time for yourselves, when the evening is fine enough and you are so placed that you can see the Sun disappear over the horizon. You should choose a spot where the horizon is clear of houses or trees, and, if possible, a spring day, when there is a keen east wind. Some people see the Flash better with a pair of opera-glasses or field-glasses.

Watch the Sun gradually sinking lower and lower until there is only the tip left. At this stage watch carefully and, just before it finally disappears, you will see a little green flame shoot up and the tip of the Sun itself will turn green. I do not say that you will always be able to see this Flash, for it is only to be seen on certain occasions. I have known people to see it only once out of a dozen times.

In any case, it is always interesting to watch the Sun set. On a clear evening you may see the interesting sight of a pink twilight glow in the east, and below the remarkable " Earth shadow " that gradually rises as the Sun sets. This is the shadow of the Earth that is thrown on the dust particles in our atmosphere, and so rendered visible. After the Sun has actually set, the clouds within the influence of the Earth shadow appear quite different in colour from those lit by the Sun, now far below the western horizon.

Often, too, when the Sun is low down near the horizon,

it loses its circular shape and appears oval. Sometimes the effect is so great that it appears almost egg-shaped. When it is low down, either rising or setting, it seems to be larger than it does when seen high in the sky. Both these curious effects are caused by the greater density of the atmosphere near the horizon. This acts as a kind of magnifying glass and enlarges the Sun. When near the " full," the Moon may also be seen enlarged at rising and setting.

A beautiful sight occasionally to be seen from Scotland or the north of England is the Aurora Borealis, or " Northern Lights." This takes the form of brightly coloured streamers of fiery mist, seen in the sky towards the north. A similar sight is seen in the southern hemisphere, where it is called the Aurora Australis, and in both cases the lights are seen best near the Poles. Exactly how these wonderful lights are caused we do not know, but they are believed to be due to the discharge of electrified particles from the Sun into the Earth's atmosphere. The auroræ appear to have a close connection with sunspots. When a magnetic storm takes place on the Sun, there are often especially beautiful displays.

During the summer months the northern sky is lit up nearly every clear night, but you must not mistake this " sun-glow " for the Northern Lights. In summer the Sun does not dip very far below the northern horizon, and so it throws up a reflection that causes the beautiful primrose-coloured glow to appear in the north. Occasionally this glow is so strong that the sky is quite light, and one can even read a newspaper by it. On the other

hand, the Aurora does not give off any great amount of light, but appears more like arches and curtains of fiery mist in the sky.

I have so far dealt with the Solar System, and the planets and comets that belong to it. Let us now learn something about the stars themselves, objects that are quite different from anything we have yet mentioned.

DATES TO LOOK OUT FOR METEORS EACH YEAR

Date	Name of "Shower"
2nd January	Draconids
20th April	Lyrids
6th May	Aquarids
28th July	Aquarids
12th August	Perseids
20th October	Orionids
14th November	Leonids
24th November	Andromedids
10th December	Geminids

CHAPTER XV

THE STARS THEMSELVES

WHEN we go outside on a clear night we can see a great number of stars, some of which look quite big and near, while others look small or very far away. Each seems to be

> "Up above the world so high,
> Like a diamond in the sky."

If we could take a long journey into space, travelling for thousands of years on a swift-flying aeroplane, and looking back at our Sun as we travelled, we should see it gradually grow smaller. As we flew on and on, there would come a time when the Sun looked only like a bright star. If we journeyed still farther, we should see it grow fainter and fainter, until at last it disappeared altogether from our sight. Such a journey is, of course, impossible, and we can never see our Sun from any other place than our Earth. We can, however, see other suns at great distances—for the stars are suns, and our Sun is a star. Many of the stars are much greater in size and brightness than is our Sun. It is because they are so far away that they look only like tiny points of light, just as our Sun would look at the same distance. It may be that some of the stars have

planets revolving around them, as our Sun has, but on this we have no knowledge.

You will now realize what a wide difference there is between a planet and a star, although they may sometimes look very like each other in the sky. A planet is a mere world circling round the Sun, but a star is itself a sun. In observing, we may generally distinguish the difference between a planet and a star by the fact that a star is always "twinkling" and that a planet seldom "twinkles," except when very low down and near the horizon. There is another way in which you can distinguish a planet from a star, but this may require a few weeks' observation. The name "planet"—from the Greek word meaning "a wanderer"—was given to these objects because they appear to wander, or move, as we should say, in relation to the fixed stars. In the same way that the Moon appears to travel through the constellations, so too do the planets appear to move among the stars. If you watch a planet for a few weeks' time you will see that it slowly alters its position with regard to the neighbouring stars. In this it is different from the stars, for the stars do not move among themselves, rising and setting in the same positions relative to one another year after year.

How grand it is to look at the heavens on a clear night! We cannot help wondering how many stars there are, for we seem to be able to see thousands upon thousands, whichever way we look. In reality, however, no person can see more than about 3,000 stars at one time with the naked eye. But of course 3,000 is not the *total* number of the stars, for if we look through even a pair of opera-

PLATE XXIII.—THE "TRAILS" OF STARS AROUND THE POLE STAR.

The white line running across the photograph from the bottom corner is a meteor.

(Photograph by W. J. Lockyer.)

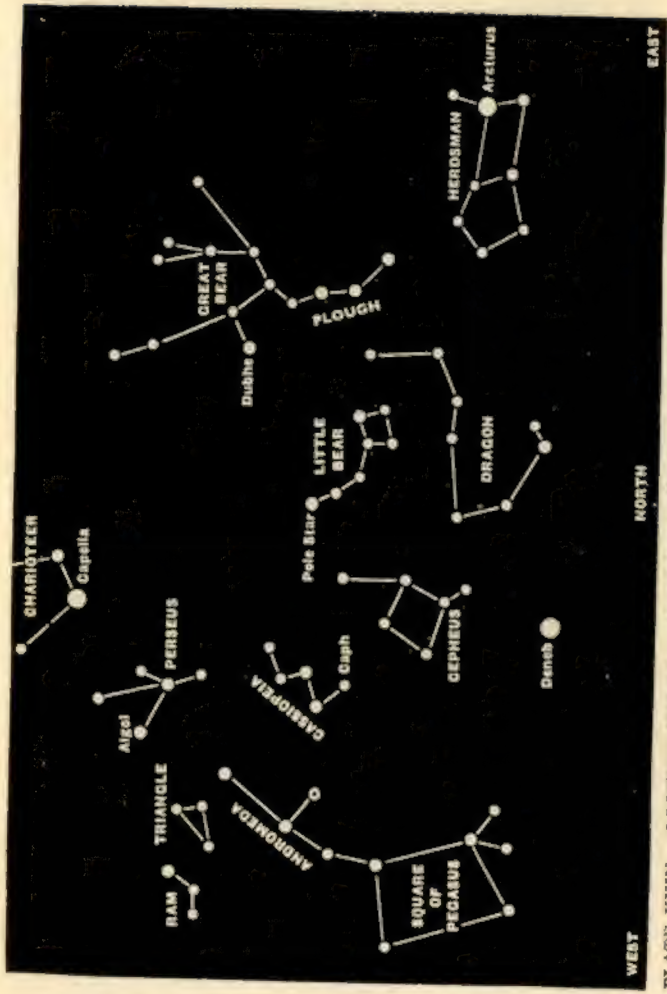

PLATE XXIV.—LOOKING NORTH: 1ST MARCH, 8 P.M.; 15TH FEBRUARY, 9 P.M.; 1ST FEBRUARY, 10 P.M.; 15TH JANUARY, 11 P.M.; 1ST JANUARY, MIDNIGHT (G.M.T.).

glasses the number visible is increased many times. A telescope shows so many stars that it is impossible to count them, and astronomers have had to resort to very carefully made estimates. As a result it has been decided that there must be over hundreds of millions of stars visible with the large telescopes of the world. We can gain some slight idea of this tremendous number when we remember that it would take a person at least a fortnight, without stopping day or night for either rest or food, to count only one million.

Long ago, before people lived in towns and cities as they do now, there was an interesting race of people called the Chaldeans, of whom we read in the Old Testament. Most of these people were shepherds, and when they were out on the hills with their sheep they sometimes had to sit all through the night guarding their flocks from the prowling wolves and other animals that were always about, ready to carry off the lambs at the first opportunity. The Chaldean shepherds were no doubt very lonely during these long night watches on the hills, for they had no lamps to lighten the darkness. Even if they had had lamps they would not have been able to do much to relieve their loneliness, for they did not know how to read or write.

There was one thing, however, that the shepherds loved to do during the long nights of watching, and this was to look at the stars, sparkling with great brilliance as they do under those far-off skies. The shepherds would often imagine quaint figures, or pictures, among the stars, exactly as we sometimes imagine we can see faces in the red-hot coals of a fire. They gave these

star-figures names, some of which remain to the present day, although many centuries have passed since those days. The shepherds did more than merely give names to these star figures, which we call the constellations, for they also made up stories about them. As the Chaldeans did not know how to write, all the stories were memorized and so handed down from father to son. Sad to say, many of the stories have been forgotten, and the names of most of the constellations have been changed by the various nations who followed the Chaldeans. Probably the Ancient Egyptians were responsible for many of the changes, whilst further changes were made by the Greeks at a later date.

The most ancient records of the constellations go back to 400 B.C., but some were named several thousands of years before that date. Other constellations were added to the more ancient ones by the Arabians, the Persians, and the Greeks. The names of most of the brightest stars are those given them by the Arabians. It is well for us to remember all this when we look up at the stars, and it is even more interesting to learn to know the constellations and to pick them out in the sky, as the ancient astronomers used to do. The stars seem like " good companions " as we see them twinkling away in the heavens. Indeed, a friend of mine, when observing with his telescope, used actually to talk to the stars as though they were his personal friends! When one thinks of the long and cold hours that the astronomer spends observing at the telescope, one might think he is lonely in the observatory. Such is not the case, however, for the stars are always with him,

and loneliness, cold, and other discomforts are quite forgotten amidst the wonders of the heavens. So, too, on a lonely road at night, the stars take the place of the trees and flowers seen by day and are the friends of those who know their names.

Here I must mention that nearly all the constellations have Latin names, and it is useful to know these as well as the English meaning. Therefore, when we come to mention them, I shall first give the Latin name and then the English. Many of the bright stars have their own names, and these you will no doubt wish to know. Another method that astronomers use to identify particular stars—and also those that have not names of their own—is by using the letters of the Greek alphabet, which are placed in front of the constellation's name in Latin. Here is the full Greek alphabet, in case you sometimes wish to refer to it.

THE GREEK ALPHABET

α	*alpha.*	η	*ēta.*	ν	*nu.*	τ	*tau.*
β	*bēta.*	θ	*thēta.*	ξ	*xī (ksī).*	υ	*upsīlon.*
γ	*gamma.*	ι	*iōta.*	ο	*omīcron.*	φ	*phī.*
δ	*delta.*	κ	*kappa.*	π	*pī.*	χ	*chī.*
ε	*epsīlon.*	λ	*lambda.*	ρ	*rho.*	ψ	*psī.*
ζ	*zēta.*	μ	*mu.*	σ	*sigma.*	ω	*ōmĕga.*

Note.—When using the letters of the Greek alphabet the Latin name is written in the possessive case. Thus, *alpha* of Ursa Major becomes α Ursa Majoris; *beta* of Perseus becomes β Persei, and so on.

CHAPTER XVI

LEARNING TO OBSERVE

BEFORE I describe the constellations and show you how you can find them, I want to tell you something about the movement of the stars during each evening. I also want to make clear to you why we see different constellations at different times of the year. These nightly and seasonal movements are always a puzzle to some people, but actually they have a simple explanation, and are not at all difficult to understand.

First of all, let me say how difficult it is to prepare a star-map from which the positions of the constellations can be found. The sky does not appear above us as a flat surface—such as the ceiling of a room—but as a vault, or inverted bowl. We must imagine that the Earth is placed at the centre of a hollow globe, the surface of which is studded with stars. We cannot see the whole of this at one time from the Earth, but only that part that is above the horizon. The other part is seen by the people in the southern hemisphere. Because of this vault-like effect, it is most difficult to draw a map of the stars on a flat surface. To do so distorts their positions to a certain extent—and especially at the edges of the map—and I want you to remember this when looking at the star-maps in this book (Plates

XXIV. to XXXV.). These show the north and south skies every two months throughout the year, so you will be able to identify the stars at any time. Please remember that the times shown for all these maps are Greenwich Mean Time. You can easily make your own calculations for the months that Daylight Saving time is in use.

In finding the different constellations we are greatly helped by the stars themselves. Once we have found the position of *Polaris*, the Pole Star, and of seven bright stars near it—the Plough—we can use them as celestial finger-posts to point to other constellations (see page 88). These again, in their turn, can then be made to direct us farther afield to new wonders.

I have already referred to the rotation of the Earth on its axis—the imaginary line that passes through the centre of the Earth. If this axis were real and not just an imaginary one, and if it could be made a little longer than the polar diameter of the Earth, it would stick out at the North and South Poles, and would be seen when explorers manage to reach those remote regions. Now, the North Pole of the Earth points almost directly to the Pole Star, which at the North Pole is seen overhead in the sky. As we in Great Britain are not " on top of the world," the Pole Star does not appear overhead, but at some distance lower (or to the north) of that point. The farther we travel toward the equator, the lower does the Pole Star appear to be. The nearer we approach to the Pole, the higher does the Pole Star rise, until—as I have said—at the Pole it is overhead.

The Earth makes a complete rotation on its axis once

in twenty-four hours, and as the axis points to the Pole Star, all the other stars appear to revolve around it. The Pole Star is like the hub of a great wheel, and the farther away a star is from this hub the greater will be its apparent path of travel through the sky. For instance, if there were a star half a degree—that is, the breadth of the full Moon—from the Pole Star it would have only a very tiny circle of revolution around the Pole. A star 20 degrees away would have a much greater circle to complete in the twenty-four hours—and so on. You will understand this more clearly by looking at Plate XXIII. This is a photograph with an exposure of two hours of the stars near the Pole Star. You will see that the stars have left a trail on the plate showing the distance they have moved during the exposure. You will notice how the stars farther away from the centre apparently follow a longer path than the stars near to the Pole Star.

Here let me explain that there are as many stars in the sky in the daytime as there are at night, but they do not show themselves because the light of the Sun prevents us seeing them. With the aid of a telescope, bright stars and planets can be seen during the daytime in full sunlight—provided, of course, that the clouds are not in the way. This is a circumstance of which many people are ignorant, for they think that the stars only "come out" at night-time. At sunset, when the light begins to fade, we see the brighter stars appear one by one, and then we realize that they must have been above us in the sky during the day.

As we watch the stars throughout an evening we see

that they, like the Sun, seem to move from east to west. In fact they, too, rise and set, and they take about twenty-four hours to return to their position, exactly as the Sun does. Their movement is, of course, also only an apparent one, for it is due to the same cause as the Sun's daily movement—that is, the turning of the Earth on its axis once in twenty-four hours.

Let us see how this works out in actual practice. We will suppose that it is 8 p.m. on 20th November. Facing north we find, low down and directly in front of us, the seven stars known as the Plough (Fig. 4). They lie almost parallel with the horizon, as shown at A, Fig. 5. Now, supposing we are sufficiently interested to stay up, we look again at 11 o'clock. The Plough is no longer where it was at 8 o'clock, but is in position B, Fig. 5. If you were able to watch for six hours, you would find it had moved from A to C. In six hours more it would be in position D; and in about twenty-four hours it will again be in position A. It thus completes the circle around the Pole Star once in twenty-four hours—because the changes in its position are due to the rotation of the Earth in this time.

No doubt you will not feel inclined to stay up to see the Plough complete anything more than a small part of the whole circle, but you can see it pass through all the positions by watching it throughout the year, and for the following reason.

I have said that the Plough completes its circle in *about* twenty-four hours. Each night the stars rise four minutes earlier than on the previous night. This represents the distance moved each twenty-four hours by the

Earth in its orbit around the Sun. Each night at 8 o'clock after 20th November, therefore, the Plough will have moved slightly farther towards the position B, Fig. 5. Thus by 8 p.m. on 20th February you will

Fig. 4.—The seven stars of the Plough and the Pole Star.

not find it at A, as it was in November, but at position C. Three months later, at 8 p.m. it will be at D, and directly overhead. On 20th August it will be at position E; to be back again at A on 20th November.

Although the stars of the Plough are to be seen all the year round from this country, some of the other

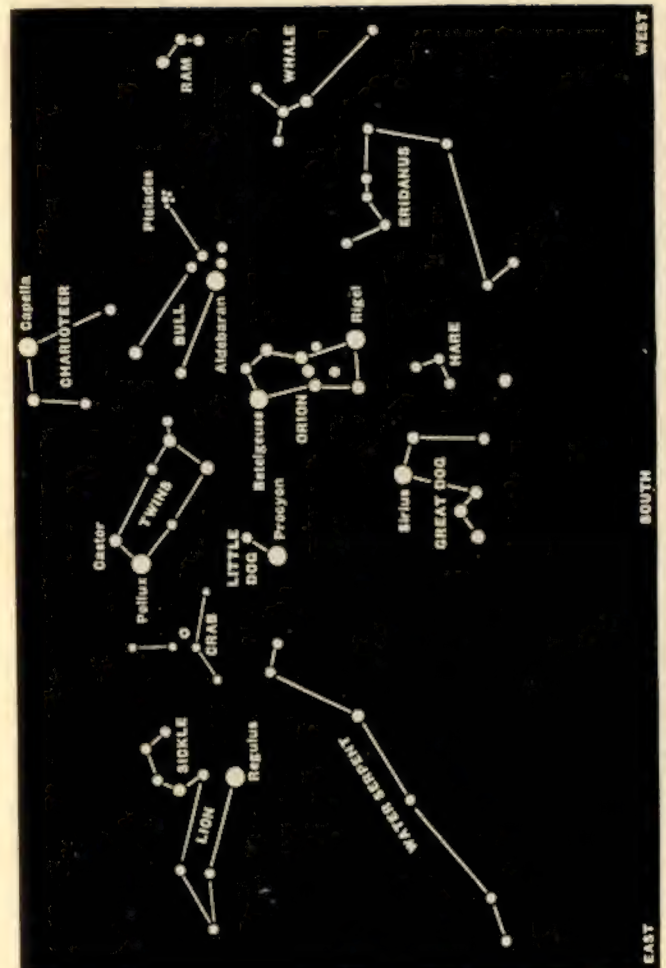

PLATE XXV.—LOOKING SOUTH: 1ST MARCH, 8 P.M.; 15TH FEBRUARY, 9 P.M.; 1ST FEBRUARY, 10 P.M.; 15TH JANUARY, 11 P.M.; 1ST JANUARY, MIDNIGHT (G.M.T.).

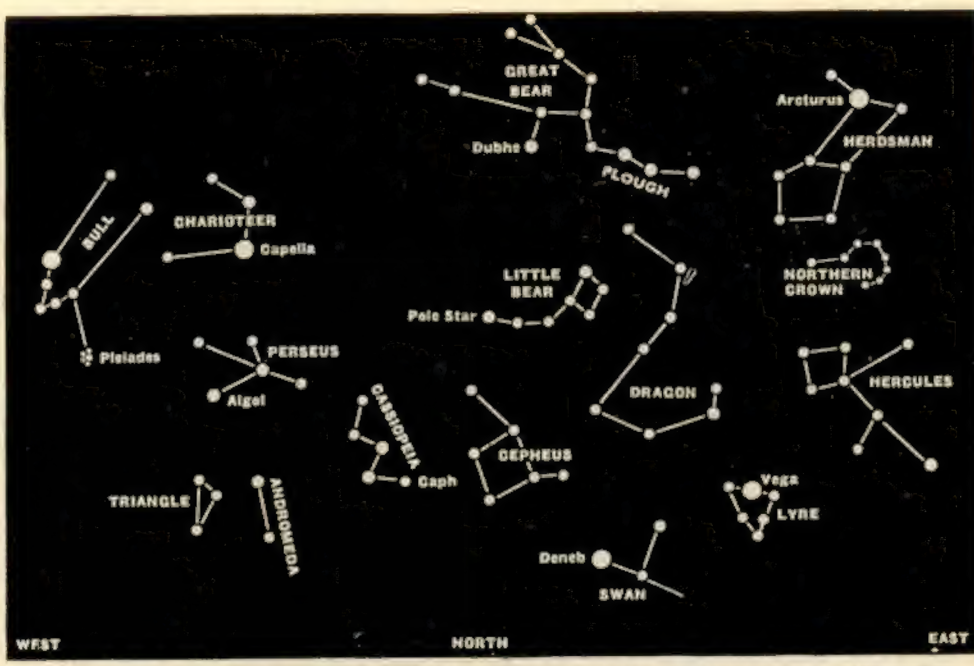

PLATE XXVI.—LOOKING NORTH: 1ST MAY, 8 P.M.; 15TH APRIL, 9 P.M.; 1ST APRIL, 10 P.M.; 15TH MARCH, 11 P.M.; 1ST MARCH, MIDNIGHT (G.M.T.).

constellations can only be seen in the winter, and others only in the summer. This is due to the movement of the Earth along its orbit. To express it in another way,

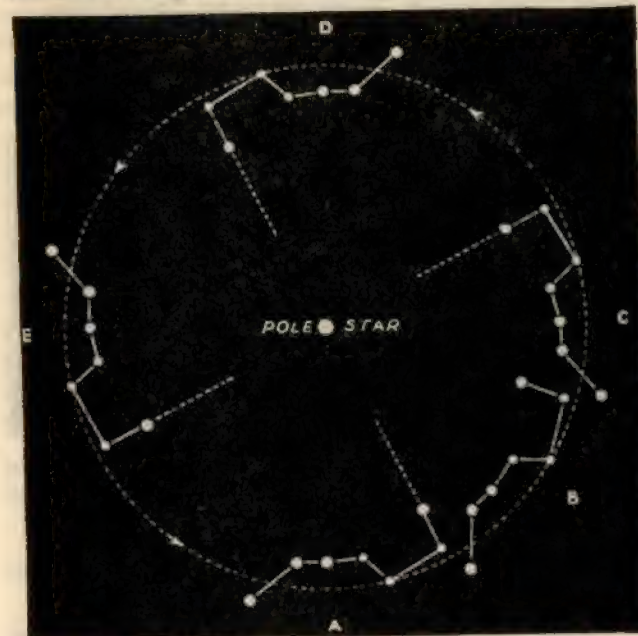

Fig. 5.—Positions of the Plough at 8 p.m. (G.M.T.) on A, 20th November; C, 20th February; D, 20th May; and E, 20th August.

by reason of the Earth's movement the Sun is found in the direction of different constellations at various times of the year. Thus it is that throughout the year we are treated to a panorama of the constellations. We

have seen that the Pole Star appears to be in the centre of the night sky, and that those stars that are near to it make small circles, while those that are farther away make bigger circles. Some are so far distant from the Pole Star that they dip below the horizon and are lost to sight for a longer or shorter time. It is these stars that seem to rise and set above and below the horizon

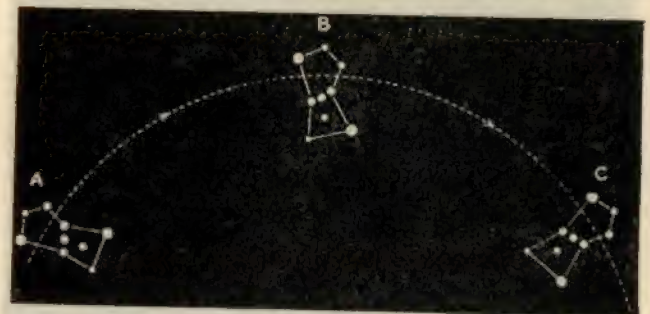

Fig. 6.—Three positions of Orion at 8 p.m. (G.M.T.) on A, 20th November; B, 20th February; and C, 20th April.

as the Sun and Moon do, whereas the stars nearer the Pole are never lost to sight below the horizon.

Let me now explain another rather puzzling matter—the apparent change in the appearance of the constellations at rising and setting. The point I want to explain is well illustrated by the constellation of Orion (see Fig. 18). If we look to the south about the middle of November at 8 p.m. we shall see this constellation rising over the eastern horizon. A couple of hours later Orion will be well visible in position A, Fig. 6. About

1.30 a.m. it will have reached B, and by 5 a.m. position C. In this position it is setting, and by 8 a.m. it will have disappeared below the horizon. Few of you will have the opportunity of watching Orion rise and set in the same night, but you will be able to see its different positions by looking for it in the early evening throughout the winter, remembering that it rises four minutes earlier each night. By February it will be in position B at 8 p.m. In April, at the same hour, it will be in position C. You will notice from Fig. 6 that Orion looks different at rising (A) and at setting (C) and when it is due south (B). Most of the constellations tilt first in one direction and then in the other as they rise and set. This difference in their appearance puzzles many people. Although at first it may seem rather confusing, we soon learn to recognize the constellations, no matter in what position they may be.

CHAPTER XVII

CONSTELLATIONS NEAR THE POLE STAR

THE seven stars of the Plough are part of the constellation of *Ursa Major*, or the Great Bear (Fig. 7), a constellation that has been known for a long time—it is mentioned in a catalogue of stars made over two thousand years ago. The seven stars are also known as "Charles's Wain" and the "Wagon and Horses," because their shape resembles, to a certain extent, the body of a wagon with its shaft. In America they are known as the "Great Dipper," and also as the "Seven Little Indians." Delving back into the past, we find that many other interesting names have been associated with these seven stars. To the Ancient Greeks they were known as *Auraxa*, "the Chariot." They were mentioned by Cicero as *Septentriones*, the "Seven Plow-oxen." To the Romans they represented a plough drawn by three oxen. They were also known as the "Seven Wise Men of Greece," the "Seven Sleepers of Ephesus," and the "Seven Champions of Christendom." The Arabs thought they represented a bier, and that the three stars in the tail were the mourners.

The seven stars have each their own name, in addition to being identified by a letter of the Greek alphabet. In Fig. 4 you will see these letters close to the stars.

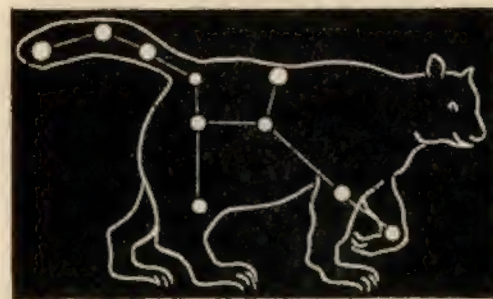

Fig. 7.—The brightest stars in the constellation of Ursa Major, the Great Bear.

The two stars marked α and β are called "the Pointers," because they always point to the Pole Star, no matter in what position the Plough may be in the sky, as you will see from Fig. 5. The Pointers help us to identify the important Pole Star, if we are in doubt at any time. Here are the names and Greek letters of these seven stars:

Greek Letter.	Name.	Meaning.
alpha	Dubhe	"the back of the Great Bear."
beta	Merak	"the loins of the Bear."
gamma	Phad	"the thigh."
delta	Megrez	"the root of the tail."
epsilon	Alioth	"the fat tail."
zeta	Mizar	"the girdle."
eta	Benetnasch	"the daughters of the bier."

As I have already mentioned, Dubhe and Merak are the Pointers that guide us to the Pole Star.

Megrez has the distinction of being the faintest star of the seven.

Mizar is very interesting because it is a double star, and near it is a small companion star. Unless you have fairly sharp eyesight you will not be able to see this little star, however, but a pair of opera-glasses will show it quite distinctly. This small star is called Alcor, meaning "the Near One." The two together were called "the Horse and his Rider" by the Arabians. To-day we know Alcor as "Jack by the Middle Horse," and in Italy it is called "the Little Starry Horseman." The Persian name for Alcor is *Saidak*, meaning "the test," for the star is so faint that it was used sometimes as a test of sight. Of course telescopes and opera-glasses were unknown in those days, but even so it cannot have been very difficult for the keen-sighted men of the East to see the two stars distinctly. Astronomers have had to ask themselves several things with regard to Mizar and Alcor. One problem was whether these two stars are really close companions, or whether they are actually not near to each other at all. It might be that they only appear to be close together, exactly as we may see from a distance two street lamps, one behind the other, looking as though they are side by side. There are many of these double stars to be seen in the heavens. Some are close companions, but others are not really near to each other, but, like the street lamps, lie one behind the other. To this class belong Mizar and Alcor.

Eta, the seventh star in the Plough, was called Benetnasch by the Arabians, who supposed the star to be one

of the three mourners following the bier, which they imagined the Plough to represent.

We have already learned where to find the Plough at different hours of the night and at different times of the year (see Fig. 5). It is necessary that we should learn to recognize it quickly, and also to be able to find the Pole Star in relation to it, for this knowledge will help

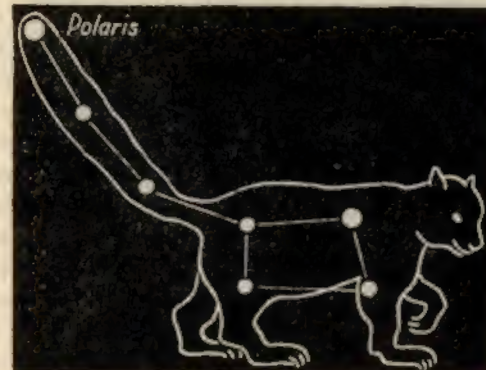

Fig. 8.—Ursa Minor the Little Bear, and the Pole Star.

us considerably in finding other constellations. There is an old rhyme that says:

> "He who would scan the figured skies,
> Its brightest gems to tell,
> Must first direct his mind's eye north
> And learn the "Plough" stars well."

Almost between the Plough and the Pole Star is *Ursa Minor*, the Lesser Bear (Fig. 8), consisting of seven stars and similar in shape to the larger Bear. *Alpha* in this

constellation is the Pole Star itself. The two stars (*beta* and *gamma*) on the extreme right in Fig. 8 are called "the Guardians of the Pole," for they circle around as though keeping watch and ward on the Pole Star. You will find that no matter at what time you observe, or whether it be during the summer or during the winter, the Guardians will always be in a position between the Plough and the Pole Star. Our great poet Tennyson in his *In Memoriam* refers to the guards as "twisting round the Polar Star."

Fig. 9.—Five stars in the constellation of Cassiopeia (see Plate XXX., etc.).

On the opposite side of the Pole Star to the Plough is the constellation of Cassiopeia, or the Lady in the Chair (Fig. 9). It is almost in a line with the Pole Star and Benetnasch, which, you will remember, is the star at the opposite end of the Plough to the Pointers. The five brightest stars of Cassiopeia look like a large letter "W." They are not difficult to identify on a clear night, and we shall find them useful later on in serving as "signposts"

to other constellations. As with the stars of the Plough and the Lesser Bear, the constellation of Cassiopeia can be seen all the year round.

If you will look towards the north-east about 10 p.m. about the end of July or early August you will see the

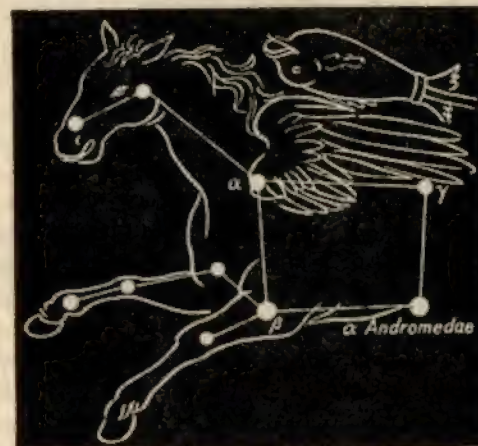

Fig. 10.—Pegasus, the Winged Horse, and (above) one of the Fishes (see Plate XXX., etc.).

four bright stars of the Square of Pegasus. The position of the Pole Star and Cassiopeia will help you to identify them, for, as you will see, Cassiopeia is about halfway between the Pole Star and Pegasus (Plate XXX.). The constellation of Pegasus was supposed by the people of old to represent a winged horse (Fig. 10). This sprang from the blood of the monster Medusa when Perseus cut off its head, of which deed we shall read again in our

next chapter. The figure of the winged horse was well known in the days of Ptolemy, having been familiar from early times. Indeed, it was used as a design on the coins of Corinth as early as 500 B.C. and for more than two hundred years later. Although a winged horse can only be made out with difficulty in the sky, the outline of the Square of Pegasus is easily found. When referring to Fig. 10 it should be remembered that the constellation is shown there upside-down, in order that the outline of the horse's head may be seen in a correct position.

If we take in two or three stars belonging to other constellations we can see the figure of a huge kite with its tail, or some call it a frying-pan! (see Plate XXX.). Four stars of the Square form the "pan" itself, and three trailing stars make the handle. The star at the left-hand corner (where the "handle" joins the "pan") is *alpha Andromedæ*, or Alpheratz; the one at the top right corner is *alpha Pegasi*, or Markab; the one at the top left corner is *beta*, or Scheat; and the one at the bottom right corner is *gamma*, or Algenib. The stars that form the handle of the frying-pan are *delta*, *beta*, and *gamma* Andromedæ. The three stars at the end of the handle are *alpha*, *gamma*, and *delta* of Perseus, of which constellation we shall learn more in our next chapter.

CHAPTER XVIII

THE LEGEND OF PERSEUS AND ANDROMEDA

THE constellations of Perseus, Andromeda, and Cassiopeia represent people about whom stories were told in Greek mythology. It is believed that although some of the stories in these legends may be partly true, most of them are purely imaginary.

The story of Andromeda and Perseus concerns a certain Ethiopian king whose name was Cepheus. Cassiopeia was his wife, and they had a daughter Andromeda who was remarkable for her great beauty. Cassiopeia boasted that Andromeda was fairer even than the goddess Juno and the Nereids, or sea nymphs. Cassiopeia's boastings deeply offended Neptune, the god of the sea, who flooded Ethiopia and sent Cetus, a great sea monster, to ravage the country. Cepheus consulted the oracle of Ammon as to what could be done to get rid of the flood and the fearful monster, of which, you may be sure, the people were greatly afraid. The oracle declared that the only way to get out of the trouble was to expose the beautiful Andromeda to the fury of the sea monster. The king decided to carry out the advice of the oracle, and ordered that Andromeda should be chained to a rock, there to await the coming of the sea monster.

Now it fortunately happened that at this time a noble youth, Perseus by name, was returning victorious with the head of Medusa, one of the Gorgon monsters.

Fig. 11.—Andromeda (see Plate XXX., etc.), showing the position of the Great Nebula (for particulars of which see page 127).

His way lay past the rock to which Andromeda was chained. When he saw her he was so struck by her great beauty that he determined to rescue her and make her his wife. Jumping on the back of Pegasus, and holding

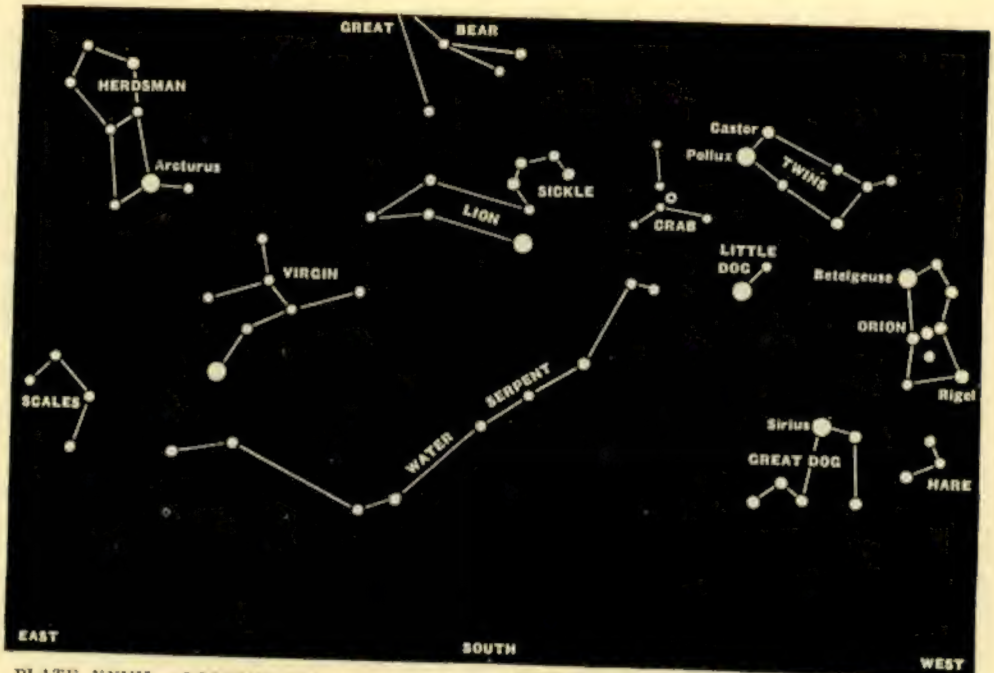

PLATE XXVII.—LOOKING SOUTH: 1ST MAY, 8 P.M.; 15TH APRIL, 9 P.M.; 1ST APRIL, 10 P.M.; 15TH MARCH, 11 P.M.; 1ST MARCH, MIDNIGHT (G.M.T.).

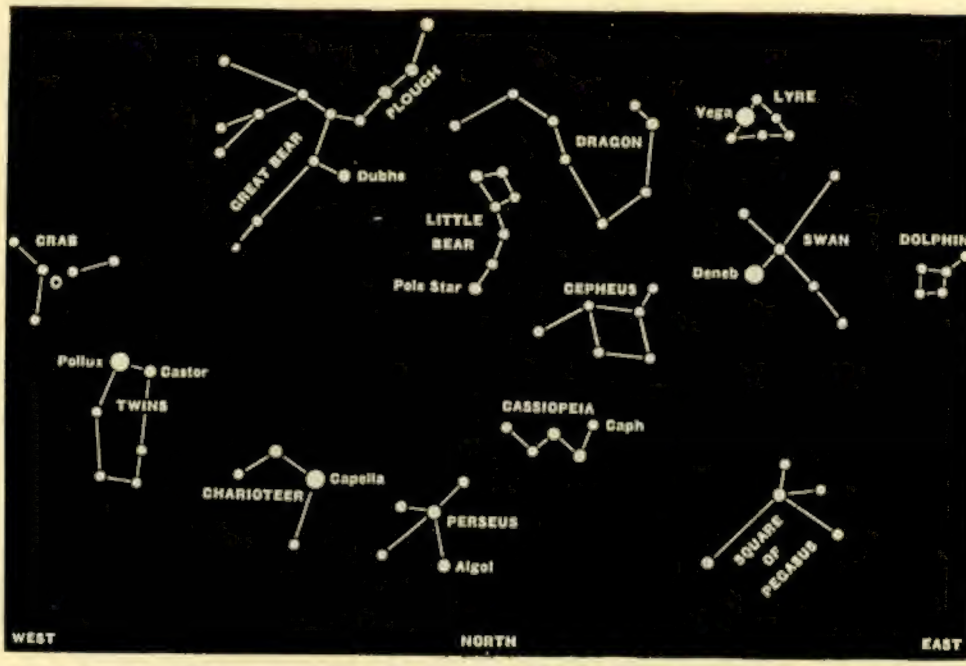

PLATE XXVIII.—LOOKING NORTH; 1ST JULY, 8 P.M.; 15TH JUNE, 9 P.M.; 1ST JUNE, 10 P.M.; 15TH MAY, 11 P.M.; 1ST MAY, MIDNIGHT (G.M.T.).

PLATE XXIX.—LOOKING SOUTH: 1ST JULY, 8 P.M.; 15TH JUNE, 9 P.M.; 1ST JUNE, 10 P.M.; 15TH MAY, 11 P.M.; 1ST MAY, MIDNIGHT (G.M.T.).

in his hand the head of Medusa—the sight of which froze all beholders with horror—Perseus arrived at the very moment that Cetus was about to devour his prey. Perseus bravely plunged his dagger into the monster's right shoulder and destroyed it. He then broke Andromeda's chains and released her, and as a reward for his gallant deed Cepheus gave him Andromeda for a wife. Some time after, the Greek goddess Minerva gave Andromeda (Fig. 11) and Perseus (Fig. 12) a place in the heavens, where you may see them to this day. Cassiopeia is there too, as we have already seen, and not far away from her is King Cepheus (Fig. 13) and Cetus, the monster of the story.

Fig. 12.—Perseus and the head of Medusa (see Plate XXX., etc.).

As we look to the east in the autumn we see Andromeda and Perseus rising above the horizon (Plate XXXII.). Taking a line from the three bright stars of Perseus and curving to the left you will come to Capella, one of the most beautiful stars in our skies. The name

means "the little she-goat," and according to the legend it was one of Capella's horns that was the origin of "the horn of plenty." Jupiter, when an infant, accidentally

Fig. 13.—The constellation of Cepheus (see Plate XXX., etc.).

broke off one of the horns when at play, and later he arranged things so that the horn had the magic power of always being filled with whatever the owner might desire. Capella was an important star in the temple worship of both Ancient Egypt and Greece. In India, where the

star also was worshipped, it was called the "Heart of Brahma." In ancient Peru it was named Colea, and was regarded as being connected with the affairs of shepherds. English poets, too, have referred to it as the "Shepherd's Star"—in his poem *Maud*, Tennyson mentions it as being a "glorious crown." Capella is the chief star in the constellation of *Auriga*, the Charioteer (Fig. 14). He carries a goat on his shoulder and two kids on his left arm. According to the legend, Auriga was placed among the stars for his invention of the chariot and the wisdom he displayed in training horses.

If we imagine another curve from Perseus similar to that leading to Capella but travelling in the opposite direction—that is, to the right instead of to the left—we come to a group of stars called the Pleiades, known sometimes as the "Seven Sisters." In Greek mythology the Pleiades were the seven daughters of Pleione and Atlas, the giant who, it was supposed, bore the Earth on his shoulders. They were said to have been placed in the heavens because of the deep sorrow they showed when the enormous burden was imposed on their father. Some people also call these stars the "Hen and Chickens," and they form one of the most interesting star groups in the sky. They are to be seen on Plate XXXII., etc.

It is a remarkable fact that, although the Pleiades have been called the Seven Sisters, a person with only ordinary eyesight can see only six stars in the group. What is even more interesting, perhaps, is the fact that not only is their number spoken of as seven throughout Europe, but the Red Indians of North America, the Ashantis of West Africa, the Chinese, as well as many

Fig. 14.—Auriga, the Charioteer, with Capella, the Little She-Goat and (just below) the Kids (see Plate XXXII., etc.).

other nations, all speak of these stars as being seven. Each nation has a story telling how the seventh star became lost. In their great national festival, "the Feast of the Lanterns," the people of Japan commemorate some great calamity that was believed to have taken place ages ago when there were seven stars in the group. It would certainly seem that at one time there were seven stars easily visible, and that one of them has disappeared, or faded until it became one of the less brilliant. Why so many widely separated nations should know of this, when the event must have happened ages ago, is a mystery.

The Pleiades have been admired in all ages of the world's history. They are mentioned in Chinese records dating from 2357 B.C. They are referred to in the Bible when Job (in Chapter XXXVIII.) speaks of "the sweet influence of the Pleiades." They were worshipped in Ancient Egypt, and were observed from the Great Pyramids. The Chaldeans, Hebrews, and Ancient Greeks all refer to them—and so we could go on, mentioning nearly every nation and every tribe, all of whom knew this delightful little star group.

When you have found the Pleiades, see how many stars you are able to count in this group on a clear night. If you have exceptionally keen sight you may be able to count nine, or sometimes ten.

Not far from Perseus and the Pleiades is another interesting object—the wonderful star Algol (Fig. 12), the position of which is shown on Plate XXXII. The Arabs called the star *El-Ghoul*, "the Demon," and it is supposed that they regarded it as a kind of "demon's eye." It was also called "Slowly Winking Star." It is peculiar because of the fact that it shines brightly, but regularly suddenly fades away until it almost seems to "go out," as it were. These variations in its brightness take place

once in every two days twenty hours and forty-nine minutes, and the "fading" lasts for a few hours. The star fades in four and a half hours, and the changes take place so regularly that they can be predicted by astronomers for years beforehand. If ever you are in doubt, you can find the exact times of Algol's fadings in *Whitaker's Almanack.*

There are many of these "winking" stars, or variables as they are called, but Algol is by far the easiest to observe. Some of the others require months instead of merely hours to fade away, and then the fading is of such slight extent that the change is only perceptible to an experienced observer.

CHAPTER XIX

OTHER CONSTELLATIONS

IF we look at the sky in the spring months and imagine a line through the Pointers, but in the opposite direction to the Pole Star, we shall see the constellation of *Leo*, the Lion (Plate XXV.). According to the Greeks, this was the ferocious lion that lived in the forest of Nemea. It was killed by Hercules, and placed among the stars by Jupiter to commemorate that famous encounter. The constellation was known in Babylonia, and to the Ancient Egyptians it was an object of worship.

Looking at the brighter stars of the constellation it is not difficult to imagine a lion in a crouching or even in a sitting position, such as those around Nelson's monument in Trafalgar Square, London (Fig. 15). Six stars form the Lion's head and chest, resembling a question mark that has been turned from left to right, thus : ?. The bottom star is Regulus, or "Little King," so called because at one time it was supposed to rule the heavens. Sometimes the six stars are called "the Sickle," for they resemble the sickle of a reaper. Shooting stars appear to come from the Sickle on or about the 13th November each year, and if you watch this part of the sky, early in the morning about this date, you will probably see

some. These particular shooting stars are called Leonids because they seem to come from that part of the sky in which *Leo* is situated.

Away to the left of Leo are several smaller stars close together, and these are called *Coma Berenice*, or the Hair of Berenice. It is said that the young queen Berenice, the wife of one of the kings of Egypt, was a very beautiful woman, and was known for the surpassing

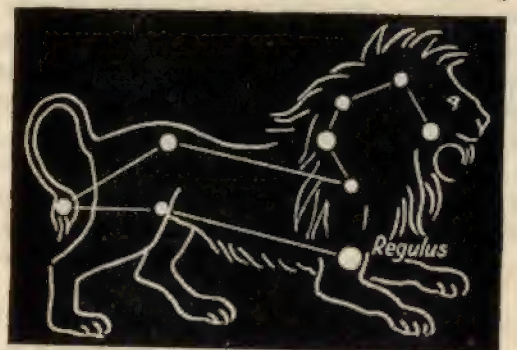

Fig. 15.—Leo, the Lion (see Plate XXV., etc.).

loveliness of her hair. She vowed to sacrifice it to the goddess Venus if her husband should conquer the enemies against whom he was about to fight. The king went away to the war, and in due course returned victorious. True to her word, Berenice cut off her hair and carried it to the temple of Venus. That night, however, it disappeared, but it was found shining in the sky, having been placed there by Venus.

Between the Hair of Berenice and the Great Bear there are a few faint stars to be seen, which go by the

name of *Canes Venatici*, the Hunting Dogs. The constellation represents two greyhounds held by Boötes, the Herdsman. They are waiting eagerly to be unleashed, so as to chase the Bear around the Pole.

If in the spring and summer we again use the stars of the Great Bear as a guide, we find the beautiful star Arcturus almost in line with the last two stars of the Great Bear's seven (Plate XXIV.). Arcturus, which is of a decidedly golden colour, was known to the Ancient Egyptians, to the Greeks, and to the Indians. Manilus, an ancient writer, described it as " the bright Arcturus, the fairest of the stars." The Arabs called it the " Keeper of Heaven," and it is mentioned in the Book of Job (Chapter xxxviii.). Arcturus is *alpha* in the constellation of Boötes, the Herdsman. According to legend, Boötes was robbed of all his goods by his brother, and after many hardships and wanderings he invented a plough that was drawn by two oxen. With this he tilled the land, and made his living following this occupation. His mother was so pleased with him that she placed him in the sky, together with the Plough.

Close to Boötes is a semicircle of seven stars. This is *Corona Borealis*, or the Northern Crown. This star-figure is not difficult to identify, for it looks exactly like a beautiful crown of sparkling diamonds (Plate XXVI.). It was known at least as long ago as 500 B.C.

Beyond the Crown lies the ancient constellation of Hercules. According to the well-known fable, Hercules displayed great courage and strength. Even when only eight months old he boldly seized two serpents and squeezed them to death! When eighteen years of age

he destroyed a huge lion that had long preyed on his father's flocks. The constellation contains the famous cluster of stars (Plate XXXVI.) discovered by Halley in 1714, and the finest in the northern sky. Here and there in the heavens we find these clusters of stars, where the stars are grouped together in great numbers. Only a few are visible without a telescope as tiny patches of light. In these clusters it almost appears as though the stars have gathered together to form universes of their own. There are more than 5,000 stars in the Hercules cluster—nearly twice as many as can be seen in the whole sky by the naked eye on a clear night! Another such cluster near the Lion, called the Bee Hive, is so thick with stars as to remind one of bees swarming round a hive, and hence its name.

Between the Great Bear and the Pole Star, and extending nearly to Hercules, is the straggling figure of *Draco*, the Dragon (Plate XXVI.). Legend tells us that this is the watchful dragon that guarded the golden apples in the garden of the Hesperides, the three daughters of Hesperus, and that it was slain by Hercules. It is a very old constellation, and was known to the Babylonians, Chaldeans, and Ancient Egyptians, as well as to the Greeks and Romans.

If you look at Plate XXXI. you will see to the left (east) of Hercules the constellation *Cygnus*, the Swan (Fig. 16). This is also called the "Northern Cross," because, as you will see, it somewhat resembles a cross in shape. You will often hear travellers speak of the "Southern Cross," the chief constellation that is seen by our friends in the southern hemisphere. All agree, however, that

the Southern Cross is not nearly as much like a cross as this constellation we call the "Northern Cross."

Between the Swan and Hercules is the constellation of *Lyra*, the Lyre. This is marked by a fine bluish-white star Vega, which, with Arcturus near by, forms a

Fig. 16.—The constellation of Cygnus, the Swan (see Plate XXXI., etc.).

brilliant spectacle. Not far from the Swan is *Aquila*, the Eagle (Fig. 17), which is made conspicuous by a line of three stars. The centre one, Altair, is more brilliant than the side ones, and yet not as bright as Vega.

The most ancient constellations are those found in the zodiac, a wide belt stretching across the heavens. This region is about thirty-two times the width of the full

Moon, and in it the Sun, Moon, and planets are always to be found. The fact that they are only found within this region of the sky was known from very early times, for the constellations that mark it date from 2700 B.C. Observations of the constellations of the zodiac enabled the ancients to measure the passing of the seasons, and

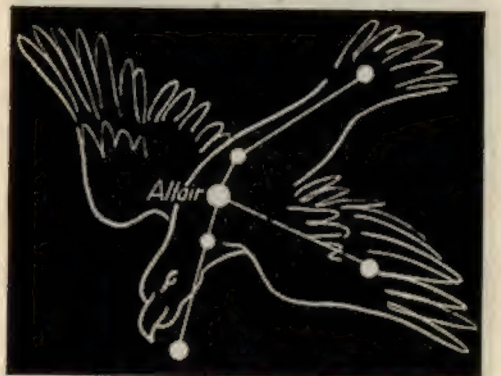

Fig. 17.—The constellation of Aquila, the Eagle (see Plate XXXI., etc.).

they were able to regulate their agricultural pursuits accordingly.

The name zodiac comes from the Greek *zodiakos*, meaning " animal circle," and it was so called because several of the twelve constellations in it have the names of animals. Some of these we have already mentioned, but others are new to us. The zodiacal constellations are: *Aries*, the Ram; *Taurus*, the Bull; *Gemini*, the Twins; *Cancer*, the Crab; *Leo*, the Lion; *Virgo*, the Virgin; *Libra*, the Scales; *Scorpio*, the Scorpion;

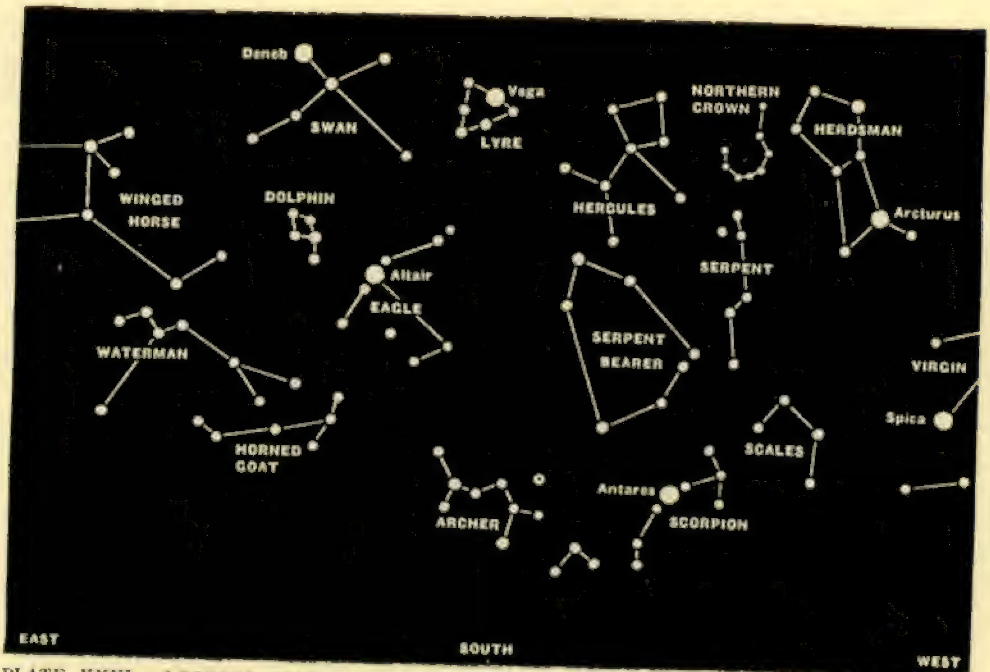

PLATE XXXI.—LOOKING SOUTH: 1ST SEPTEMBER, 8 P.M.; 15TH AUGUST, 9 P.M.; 1ST AUGUST, 10 P.M.; 15TH JULY, 11 P.M.; 1ST JULY, MIDNIGHT (G.M.T.).

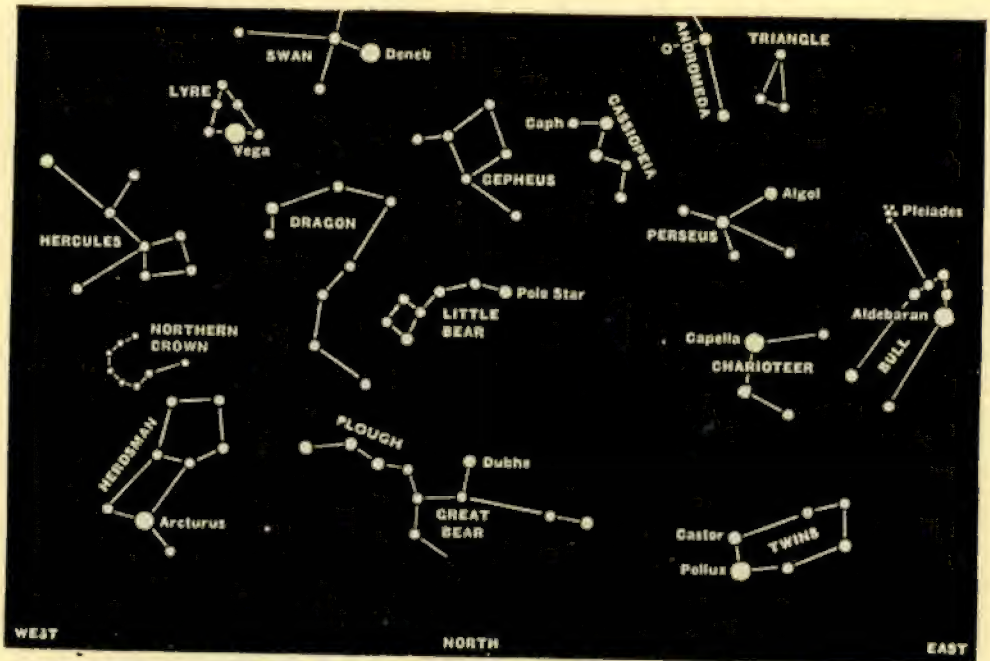

PLATE XXXII.—LOOKING NORTH: 1ST NOVEMBER, 8 P.M.; 15TH OCTOBER, 9 P.M.; 1ST OCTOBER, 10 P.M.; 15TH SEPTEMBER, 11 P.M.; 1ST SEPTEMBER, MIDNIGHT (G.M.T.)

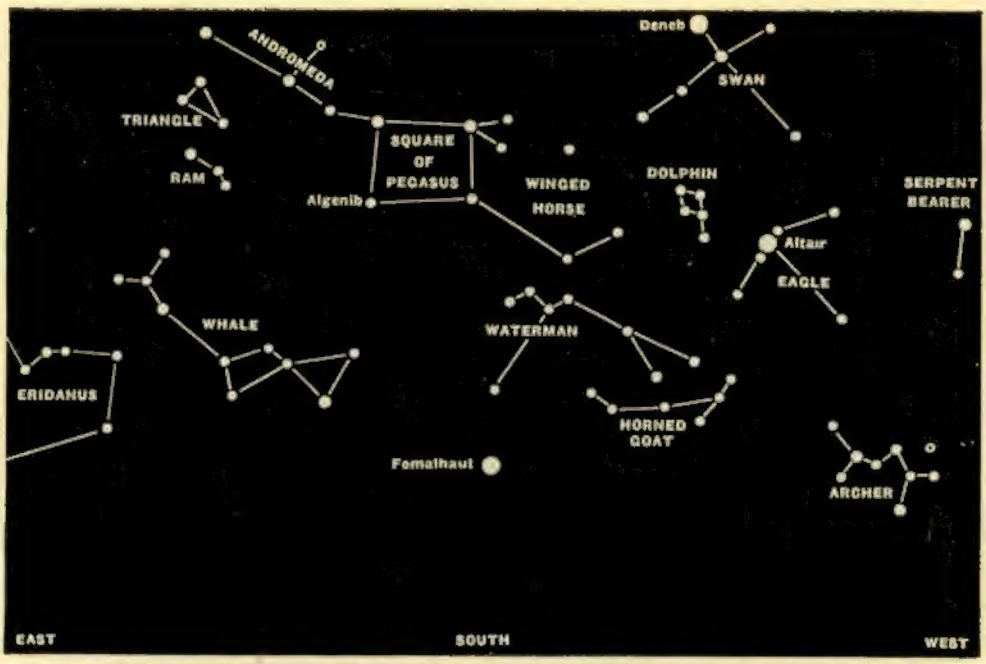

PLATE XXXIII.—LOOKING SOUTH: 1ST NOVEMBER, 8 P.M.; 15TH OCTOBER, 9 P.M.; 1ST OCTOBER, 10 P.M.; 15TH SEPTEMBER, 11 P.M.; 1ST SEPTEMBER, MIDNIGHT (G.M.T.).

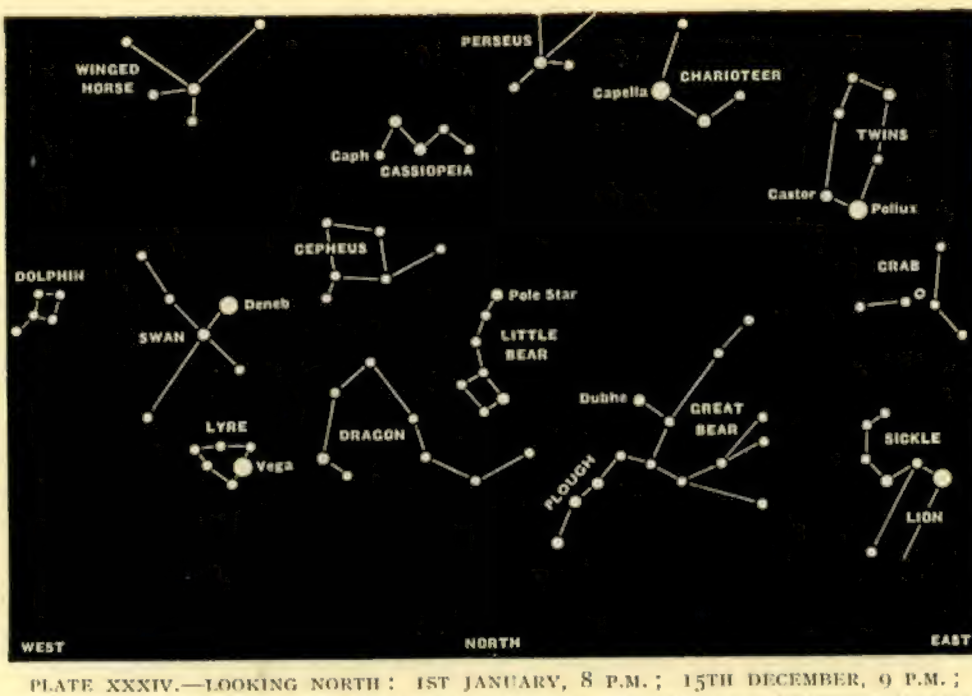

PLATE XXXIV.—LOOKING NORTH: 1ST JANUARY, 8 P.M.; 15TH DECEMBER, 9 P.M.; 1ST DECEMBER, 10 P.M.; 15TH NOVEMBER, 11 P.M.; 1ST NOVEMBER, MIDNIGHT (G.M.T.).

Sagittarius, the Archer; *Capricornus*, the Goat; *Aquarius*, the Water-carrier; and *Pisces*, the Fishes. This sounds a rather formidable list, but there is a little verse that will enable you to remember these star-figures, and the order in which they follow each other in the zodiacal belt. It runs thus:

> The Ram, the Bull, the Heavenly Twins,
> And next the Crab the Lion shines,
> The Virgin and the Scales;
> The Scorpion, Archer and Sea-Goat,
> The Man who pours the water out,
> And Fish with glittering scales.

Many of these zodiacal constellations are small and inconspicuous, but I have drawn each of them in the star-maps so that you may identify them should you wish to do so.

I have dealt only with the best-known conspicuous constellations, but there are many other smaller ones that I hope you will some day learn to identify. As perhaps you will have realized, many of the constellations do not bear much resemblance to the shapes they are supposed to represent. Despite this, the forms in which they are arranged enable us to identify them and to learn the positions of the stars. You will be surprised to find how interesting it becomes to be able to point to a bright star and to name it, or to be able to say to which constellation it belongs. Perhaps, too, a friend may wonder how the stars came to get their names, and you will then be able to tell of the shepherds on the hills in far-off days, and of the stories they made up about the constellations.

CHAPTER XX

THE CONSTELLATION OF ORION

OF all the star-figures, perhaps the most brilliant is that of Orion, the Giant Hunter (Fig. 18). According to the Greek legend, Orion was the greatest hunter in the world, and he claimed there was no animal that he could not overcome. A scorpion bit him in the foot, however, and thus his boast was a vain one.

The constellation is to be seen during the months of late autumn, winter, and of early spring, and you will be able to identify it easily. If you look carefully you can make out the shape of a giant figure marked by the stars. Two bright stars, Bellatrix and Betelgeuse, show the place of Orion's left and right shoulders; another star, lower down, marks his right knee. The beautiful blue-white star Rigel marks his left foot. Three smaller stars in a line are his belt, below which are some more stars representing the jewelled handle of his sword. The Hunter is swinging a great club in his right hand, while over his left arm is a lion's skin.

Near Orion are his faithful dogs. If you look a little to the left of Orion and nearer the horizon you will see *Canis Major*, the Greater Dog (Fig. 19). In this constellation is Sirius,* by far the brightest star in the whole of our skies, and often referred to as "the Dog Star."

* Pronounced "Sire-e-us."

Canis Minor, or the Lesser Dog, is near by, but higher up. The chief star in this constellation is Procyon, and although not as bright as Sirius, it is a beautiful object.

Fig. 18.—Orion, and Taurus the Bull (see Plate XXV., etc.).

It is interesting to notice the colours of the four brightest stars in this part of the sky. Sirius and Rigel are steel-blue, Betelgeuse is orange, and Procyon is yellow-white.

Another constellation connected with Orion is *Taurus*, the Bull, and it is this animal that Orion is supposed

to be hunting through the heavens (Fig. 18). The full figure of the Bull is not seen, but only the head, horns, and forelegs. It is charging down on Orion, and he is holding up his left arm to protect himself, while with his right he wields his great club.

Somewhat above the Lesser Dog are two bright stars known as *Gemini*, the Twins. They were called the

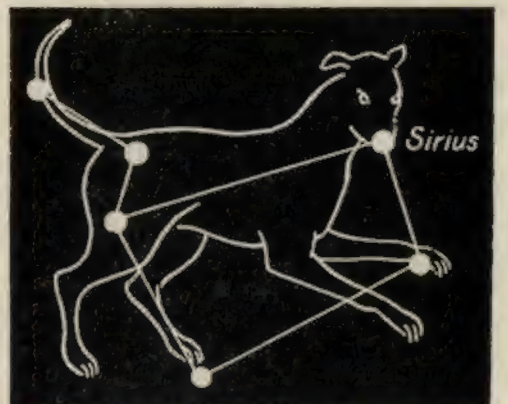

Fig. 19.—Canis Major, the Greater Dog (see Plate XXV., etc.).

" Giant's Eyes " by the early English people. Ages ago, so the story goes, there lived a giant called Daze, and he was so clever that he was able to take the shape of any bird or beast at will. He generally assumed the form of an eagle, however, and in this guise he would fly about the land, seeing what he could pick up from men. On one of his journeys he came across three gods encamped under a tree. They had just killed an ox, and

had lighted a huge fire with which they intended to cook it, for they were hungry with travelling far.

Giant Daze, in the form of an eagle, perched himself on a tree, and as he was well versed in witchcraft, he cast a spell over the pot, commanding that the meat should not be cooked until he pleased. The gods began to think that they were never going to have their meal, when giant Daze cried out from the tree above, " What will you give me if I make the meat cook ? " " We will give you a share of the meat," answered the gods. With that the pot began to bubble and boil as it had never done before, and before long the meat was cooked. One of the gods, who was known by the name of Loke, took off the lid and was about to lift out the meat, when giant Daze swooped down from the tree and caught up the best part of the meat in his claws, leaving only the bones behind. On this, Loke jumped up, and catching up a pole that lay near at hand, dealt Daze a great blow. Daze was ready for this, however, and he cast a spell on the pole so that it remained fast to his back, and Loke's hands stuck fast to the pole ! Away flew Daze, with the meat in his claws and with Loke hanging on to the pole ; but the weight of both was so great that the giant could only fly near to the ground. In consequence of this, Loke's feet were bumped against the rocks and stones, while his body was badly scratched by thorns and bushes.

Daze then made Loke promise to bring him the Apples of Youth, and on his consenting to do this, released him from his hold on the pole. After many adventures, Loke managed to bring Daze the apples that ensured

everlasting youth, but the gods were so angry with Loke for having stolen them that they bade him get them back from Daze, and even threatened to kill him should he fail to do so. So Loke impersonated a bird and flew away to Daze's house. The giant was out, but Loke, seeing the Apples of Youth on the table, caught them up and flew homeward with them. Shortly after his departure Daze returned, and finding the apples gone, changed into his eagle's shape and flew after Loke at top speed. Having more powerful wings than Loke, the giant overtook him just when he drew near to the god's city. All the gods were on the city walls watching the race, and seeing that Loke was being closely pursued by Daze, they obtained a quantity of shavings and set them along the top of the wall. As soon as Loke, with the Apples of Youth in his grasp, had flown over the wall, the gods set fire to the shavings, and Daze, being so close behind, and flying so fast, could not stop himself, but flew into the centre of the blaze. The flames burnt all his feathers, and down he fell to the ground, and there the gods slew him. They placed the giant's eyes in the sky, and they may be seen there to this day, but they are now called the Twins.

CHAPTER XXI

THE STARS IN MOTION

IN a previous chapter we saw that stars do not appear to move in regard to one another. One of the most wonderful things that we know about the stars, however, is that most of them *are* moving. In 1718 Halley —about whose comet we have already read—discovered that Sirius, Procyon, Arcturus, and other bright stars had moved their positions very slightly in regard to some of the stars near them. Since that time it has been found that all the stars are moving through space.

Our Sun is one of these travelling stars. Together with the planets, comets, and meteors, that make up the Solar System, he is travelling towards a part of the sky not very far distant from the beautiful star Vega, in the constellation of the Harp. Other stars are moving also, but not all at the same speed. The Sun and planets are travelling towards Vega at a rate that is greater even than the swiftest rifle-bullet, for every hour sees us over 40,000 miles nearer that part of the heavens.

The star with the swiftest movement of all is one discovered by Professor Barnard from his photographs. It is called " Barnard's Star," but is known also as the " Runaway Star," for it is estimated to be travelling at over 200 miles per second. Just imagine, if you can,

this terrific rate of motion! We considered Sir Malcolm Campbell to be travelling at a tremendous speed when he won the land-speed record at 246 miles per hour, but the " Runaway Star " travels in one minute more than *Bluebird* could do in two days and two nights, with no stops for petrol! Another rapidly moving star is that called by astronomers " 1830 Groombridge," because this is its number in a catalogue of stars made by an astronomer of that name. This star travels at 138 miles a second. Aldebaran and Altair travel at 8 miles a second; Vega at over 10 miles a second; and Arcturus at 89 miles a second.

Perhaps you would be interested to know how astronomers have discovered that the Sun is moving towards Vega. As you walk through a wood the trees in the distance appear close together, but as you approach them they seem to open out. Now astronomers found that the stars are opening out in a certain part of the sky not very far distant from Vega. When they came to think the matter over, they decided to look behind, as it were, at the stars in the opposite part of the heavens, as you might look behind at the trees when you walk through the wood. When the astronomers had made their observations, they found the stars in that opposite part of the sky seemed to be closing in! Here was a great discovery, for to account for what was seen it was clear that the Sun and the Solar System must be travelling towards Vega. What new stars will be seen as the Earth journeys through space we cannot say, but the celestial distances are so vast that countless ages must pass before even a slight change

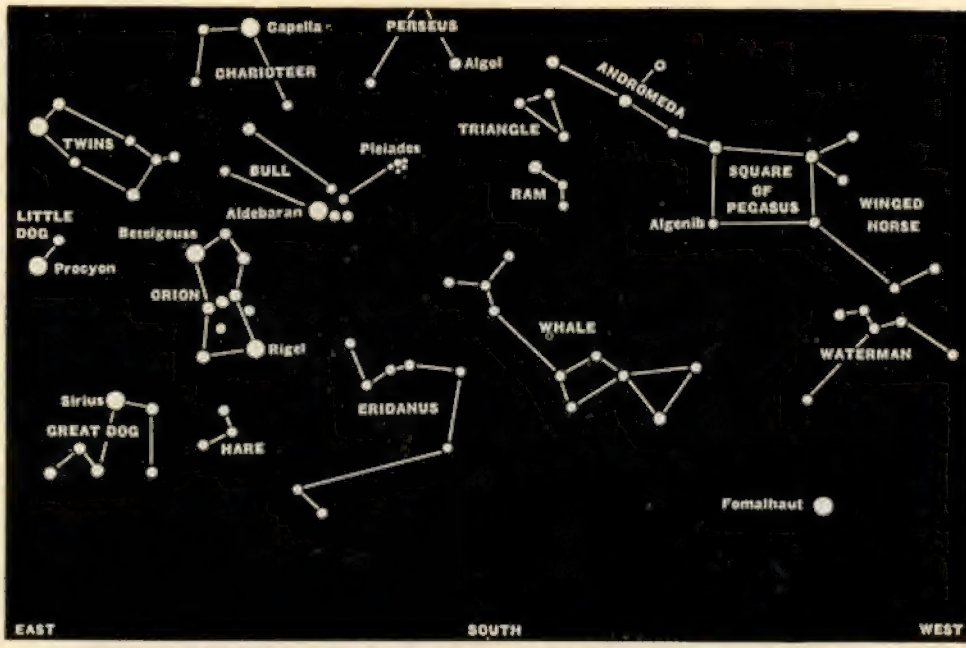

PLATE XXXV.—LOOKING SOUTH: 1ST JANUARY, 8 P.M.; 15TH DECEMBER, 9 P.M.; 1ST DECEMBER, 10 P.M.; 15TH NOVEMBER, 11 P.M.; 1ST NOVEMBER, MIDNIGHT (G.M.T.).

PLATE XXXVI.—THE WONDERFUL STAR CLUSTER IN HERCULES.

takes place in the arrangement of any of the constellations as they exist in our sky.

Not only has it been discovered that the stars are not "fixed," as the ancients believed, but it has also become clear that the stars are not moving this way and that, or indiscriminately, as we should say. They are travelling in streams, exactly as we know that flocks of birds fly away from England to warmer countries when the cold weather comes. These birds are called "migrating birds," and as many of the stars seem also to be travelling in "flocks" they have been called "migrating stars." For instance, five of the stars of the Great Bear are travelling in apparently the same direction, and Sirius, the Dog Star, is also moving in the same direction as they are. The Pleiades are another instance, for nearly all the stars in this beautiful group are travelling in the same direction. They are not travelling towards the same part of the sky as the five stars of the Great Bear and Sirius, however, nor are these stars travelling towards Vega, in the direction in which our star—the Sun—seems to be moving. There are many other "flocks" of stars travelling in other directions, but the discovery of the migrating stars has only been made comparatively recently, and the subject is one that is now receiving the closest attention.

Here I may mention that not only do stars differ in brightness, but they also differ in colour, a fact that we have noticed already. Look, for instance, at Vega, which is of a decidedly blue colour, and compare it with the golden-yellow star Arcturus, not far away. Sirius is blue-white, and Capella almost pure white, but Alde-

baran, in the constellation of the Bull, is of a decidedly red colour. We have seen that the stars are suns, some of them more beautiful and many times greater than our Sun. Some astronomers think that the older a sun gets the redder it becomes in colour. When the star is " young " it is blue-white, and as it grows older it changes first to yellow, and when almost burned out it assumes a red colour. You will know that, in order to tell the age of a horse, a dealer looks at its teeth. When the astronomer wishes to gain some idea of the age of a star he looks at its colour, and by this means he can roughly ascertain its age as a sun. The age of a star cannot be measured in " years," for many millions of years may pass before the slightest change takes place in a star's colour.

CHAPTER XXII

THE NEBULÆ

I WISH now to tell you something of the nebulæ, of which there are vast numbers scattered about the heavens. *Nebula* is a Latin word meaning " a cloud," and the name is very suitable, because the nebulæ look like tiny clouds, and actually many of them are enormous clouds of gas.

Although one or two of the larger nebulæ may be seen with the naked eye on a very clear night, looking like tiny specks of mist against the dark background of the sky, most of them cannot be seen without the aid of a telescope. Even then they are not seen in all their wonderful beauty. The best way in which to study them is to examine the photographs of them, which have been obtained with our great reflecting telescopes.

Nebulæ have been called the " Workshops of the Creator," and for this reason. Everything has to have a beginning, and the material from which things are made is often so unlike the finished object as to afford no clue to its origin. For instance, there is no resemblance between a mass of steel ingots and the locomotive into which they are made by the engineers. We understand that the planets have not always been

as they are at the present time. They have been gradually formed, or evolved as it is called, from material of quite a different appearance, but in their case the work has not been done by human hands. If you are specially interested in this subject you can read more about it in another book I have written for you. It is called *The Earth*, and it also is one of the " Shown " Series, to which this volume belongs.

We believe that many of the nebulæ are the beginnings of countless suns and planets. How grand it is to be able to look at these wonderful objects—to think that we are looking right into the " Workshops of the Creator," and that we are able to see suns like our Sun in the process of formation. We can imagine that perhaps, in the course of time, these suns may have planets circling around them, as our Sun has at the present time.

The stars are a long way off, but the nebulæ are even farther away than most of the stars. You will remember that, when speaking of the Earth's distance from the Sun, I used an illustration of a railway train. Were I to attempt to illustrate the distance of even the nearest star in the same manner, you would not have any clear conception of the vast gulf of space that separates it from us—the distance is so great that mere figures have no meaning. However, I may be able to give you a slight idea of the distance of the nearest star by using another method of illustrating it.

When a gun is fired at a distance of, say, a mile, we first see the flash, and a short time afterwards we hear the " bang ! " Now the reason we do not see the flash

and hear the report both together is that sound travels much more slowly than light. It is the same with thunder and lightning, for although the thunder occurs at the same instant as the flash of the lightning, we do not hear the thunder until a little time after we have seen the flash. This is because the light travels more quickly than the sound. Sound travels at the rate of about 1,111 feet a second, but light, which is infinitely swifter, travels about 186,000 *miles* a second. At this rate light from the Moon would reach the Earth in a second and a quarter, and from the Sun in eight minutes. For light to reach us from the nearest star takes over four years and four months ! If you are good at arithmetic you can find out from this how many miles away is the nearest star. Find how many days there are in four years and four months, multiply that figure by 24 to find the number of hours ; then by 60 to find the number of minutes ; and again by 60 to find the number of seconds. Finally, multiply that figure by 186,000, the number of miles light travels per second. Your answer will be the distance to the nearest star in miles ! Most stars are much farther away even than this.

Star distances are so great that astronomers do not speak of them in miles, but refer to them as " light years," saying, for instance, in the case of the nearest star, " It is over four light years away from us." Expressed in this way, Sirius is over 8½ light years away ; while Vega, that beautiful bluish star near Cygnus, is at a distance of 27 light years. The distances of some of the other stars are : Aldebaran, the chief star of the

Bull, 32 light years; Capella, near Perseus, 32 light years also; the Pole Star, 47 light years; and Arcturus, 160 light years. It is interesting to remember, when looking at the stars, that we are not seeing them as they are *now*, but as they were so many years ago. For instance, suppose that Arcturus were to be extinguished to-day, it would still continue to shine in our skies, with undimmed brilliance, for another 160 years.

The distance of even the nearest star is past our understanding. What then are we to think of the distance of the nebulæ, the nearest of which is at an infinitely greater distance than the stars. Let me try to convey some idea of this enormous distance. Suppose we were to construct a tiny model of the Earth's orbit around the Sun. We represent the mighty Sun by a microscopic speck of dust. As the actual distance of the Earth from the Sun is about 92,000,000 miles, the diameter of the Earth's orbit is therefore 184,000,000 miles. In our tiny model we represent this by the head of a pin! On this scale the distance of the nearest star will be 232 yards. On the same scale the distance of the nearest nebula will be 32,000 *miles!* Even on the scale of our model we cannot imagine that distance clearly—how much less are we able to comprehend the actual distance it represents!

There are hundreds of thousands of nebulæ in the heavens, but most of them are only visible with powerful telescopes. One of the best known is that in Orion, situated in the sword handle under Orion's belt. With a good pair of field-glasses you will be able to see that one of these stars is surrounded by a patch of misty

light. This is the Great Nebula, of which you will see a photograph on Plate XXXVII.

Another famous object (Plate XXXVIII.) is the Spiral Nebula in *Canes Venatici*, the Hunting Dogs. This nebula seems to be whirling round, like the whirlpools one sees in a river, and for this reason it is sometimes called the "Whirlpool Nebula." We cannot actually see the nebula whirling, of course, for its distance from us is too great—it is probably situated at a distance of over 100,000 light years! Sometimes when we are at the seaside we may notice a steamer out at sea. If we look again in a few minutes' time, the steamer will still seem to be in the same place, not appearing to have moved at all, although we know it may be travelling through the ocean at a speed of many knots. Because of our great distance from the steamer, it does not seem to move in so short a time as a few minutes. It is the same with the nebulæ, for a man's lifetime is like our glance at the steamer. We may look at a nebula when we are quite young, and again when we are old, after the passing of many years, yet it will still appear to be in the same position. It will not seem to have moved, although it is probably actually whirling round at a great speed.

Before concluding this chapter I must mention one other famous nebula—the wonderful nebula in Andromeda, the position of which is indicated in Fig. 11 and in the star-maps. This nebula was known as far back as the year 905, long before telescopes were invented, and about that time it was named the "Little Cloud." It has also been referred to as "the Wisp of Night"

and the "Queen of Nebulæ." It can be seen quite plainly with the naked eye, looking like a misty star. Both this and the Whirlpool Nebula belong to a different class from that of the Orion nebula, which is not a spiral. It is believed that they do not consist of gas, but that they are composed of enormous numbers of stars, so far away that not even their brightest members can be distinguished. They seem to be great star systems, and for this reason are sometimes called "Island Universes."

PLATE XXXVII.—THE ORION NEBULA.

(From a photograph by Ellison Hawks.)

PLATE XXXVIII.—THE SPIRAL NEBULA IN CANES VENATICI.

(From a photograph by Dr. Max Wolf.)

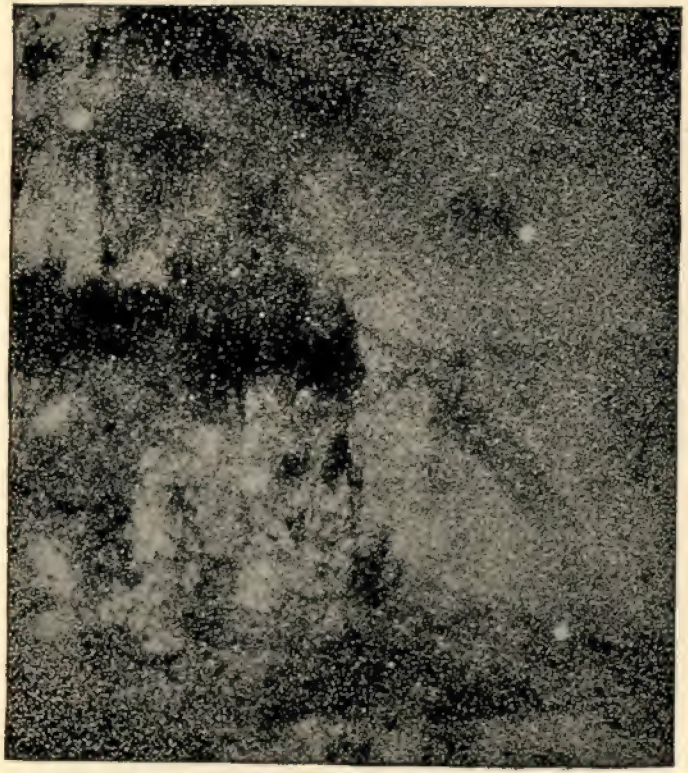

PLATE XXXIX.—PART OF THE MILKY WAY.
(*Photograph by E. E. Barnard.*)

PLATE XL.—PART OF THE MILKY WAY SHOWING "DARK LANES."

(Photograph by E. E. Barnard.)

CHAPTER XXIII

THE MILKY WAY

ON a clear fine night a band of misty light may be seen stretching across the sky. It has been known since the earliest times, and has been called by many names. To the Hebrews it was "the River of Light," and to the Chinese and Japanese the "Celestial River" or "the Silver River." In olden times in England it was called "the Fairies' Path." To-day we know it as the galaxy, and because this name comes from the Greek word *gala*, meaning "milk," it is also known as the Milky Way.

The Milky Way stretches in a broad luminous band across the heavens, and is more distinct in some parts than in others. In the north, in Cassiopeia and Perseus, it is rather faint, but is much brighter near *Cygnus*, the Swan. In the south, between *Aquila* and *Sagittarius*, it is very clearly seen, and hereabouts it has many patches of bright light. It will be noticed, too, that there is a second and fainter stream of light near to it and running parallel with it.

Actually the Milky Way is composed of countless numbers of stars. Their distance is so great that the eye cannot see them separately, and only their combined light reaches the Earth. Look at the photograph repro-

duced in Plate XXXIX., and you will obtain some idea of its wondrous beauty. Even in this one photograph of a small part of the Milky Way the stars are so numerous that we cannot count them—if you have any doubts on the point, just try! It is a sight that we are unable to understand—one that is all the more wonderful when we remember that each one in this multitude of stars is a sun, some of them, perhaps, many times greater and more brilliant than our Sun. This photograph is not the only one that has been taken of the Milky Way—there are hundreds of others, each showing countless numbers of stars as this picture does (see Plates XL. and XLI.). You will now understand the difficulty in estimating how many stars the Milky Way contains.

Some of the photographs of the Milky Way show extraordinary dark spaces. It seems almost as though some one might have taken a spade and shovelled the stars to one side, as though they were snow. There are numbers of these dark regions, one of the best known being that shown in Plate XL., which is part of the Milky Way near *theta* in the constellation *Ophiuchus*. Towards the top of the photograph you will see a large dark area, and near the centre several dark thread-like "lanes." Some of the dark regions to be found in the constellation of *Cygnus*, the Swan, seem to be so black that they are sometimes called the "Northern Coal Sacks." At one time it was supposed that these dark regions were holes in the star clouds, and that through them we looked into the depths of space. There is every reason to believe, however, that this is not the

correct explanation, but that the dark lanes are caused by dark clouds of gas—"black nebulæ" in fact—that come between us and the Milky Way and hide parts of it.

Some astronomers think that our Sun really belongs to the Milky Way, and that the Milky Way and all the stars we know make up a great star cluster. Others think that the stars of the Milky Way are arranged in spirals, and that the wonderful spiral nebulæ—such as the Whirlpool Nebula in *Canes Venatici*—are other Milky Ways, composed of billions of stars. On this wonderful subject it is too early to speak more definitely as yet, and we shall have to wait until further observations can be gathered and studied before a more certain pronouncement can be made.

CHAPTER XXIV

ASTRONOMERS AND THEIR WORK

NOW that we have seen some of the wonders of the heavens, it will perhaps be of interest to learn something about astronomers and their work. Often people have said to me: "What is the use of spending hours and hours gazing through a telescope, especially on a cold night?" I am sure you will understand that there is something more to be done than simply "gazing through a telescope." On fine clear nights we make our observations at the instrument, and make notes of what we see in an Observation Book. Those who have the ability make drawings or take photographs, as the case may be. When the nights are cloudy, and no stars to be seen, we work out our observations, and in this way no time is lost.

In the larger observatories the work is arranged on a carefully-thought-out programme. As far as possible the astronomers of the different observatories co-operate, or work together, so that every problem may have its share of attention. Some study the Sun or investigate the composition of the different stars. Others photograph the nebulæ, or measure double stars or star distances.

In recent years a great astronomical undertaking has

been in progress. This is the making of a complete photographic chart of all stars above a certain brightness. For the carrying out of this great task eighteen observatories in all parts of the world have been working together. In order that the photographs may all be on a uniform scale, each observatory has used a certain size of telescope. The sky was divided into 22,000 squares, and each observatory undertook to obtain a definite number of photographs. A thousand photographs are taken each with six minutes' exposure, and another thousand with forty minutes' exposure. In this way it is expected that, when completed, the photographs will show over fifty million stars. The undertaking is so great that, although the work has been going on for many years, it is even yet far from being completed. Although some of the observatories have finished their share of the work, others have yet a great deal to do. At Greenwich and Oxford, two of the observatories taking part, are hundreds of photographs of different parts of the sky, and each is carefully indexed and filed in its place.

The difficulties that arise in connection with the work are not all connected with the heavens, for in some cases they have a terrestrial origin. For instance, among those countries that have not yet been able to complete their share of the work is a certain republic where they are always having revolutions. There is so much fighting that the astronomers have been unable to get on with their work. A few years ago a traveller told me that he was passing through the principal city of another country that had promised to take part in the

photographing of the stars. Being interested in astronomy, my friend asked to be shown over the observatory. Here he expected to see piles of star-photographs, arranged and indexed like those at Greenwich and Oxford. Instead of this, however, he found the observatory closed, and in the charge of an old caretaker, who took him to see the telescope which was, as he said, "tc picture every star in creation!" But the traveller found that some one had fired a bullet through the telescope, which was so damaged as to be of no further use. The caretaker said that the astronomer who had charge of the observatory had been sent to prison because his politics were not favoured by the new government. So, you see, the paths of astronomers are not always as smooth as they are sometimes said to be!

Another great work was the photographing of all the nebulæ in the sky. This was commenced by Professor Keeler, the Director of the Lick Observatory in California, but soon after he had commenced his great task he was taken seriously ill and died. Had he lived he would have accomplished a most valuable work, for he obtained some of the finest celestial photographs that have ever been taken. As it happened, certain people who wished to commemorate his memory decided to have copies taken of all Professor Keeler's nebulæ photographs. These were bound and issued in the form of a book, and I am sure you will agree with me that a monument of this kind is far more useful than any marble statue, no matter how beautiful it may be.

Those observatories that make a special study of the Sun record its appearance day by day. Every

clear day, photographs are taken at Greenwich Observatory. When the day is cloudy, and it is impossible to obtain a photograph of the Sun, the Astronomer Royal writes to the observatory in Mauritius, where the skies are more often clear than in England. The astronomers on that far-away island then send a copy of their photograph for the day that was cloudy in England, and in this way there is a complete record all the year round.

Another special branch of research is that devoted to a study of the chemical elements and the physical condition of the Sun and stars. This work is carried out by means of the spectroscope, a word that comes from the Greek *skopeo*, "I view," and the Latin *spectrum*, "the appearance."

The chief part of the spectroscope is a prism. This splits up the light received from a star, and enables the astronomer to learn not only of what the star consists but also its present condition. The spectroscope also enables us to determine the speed at which a star is moving, and whether it is approaching or receding from the Earth. It gives us a great deal of information that cannot be obtained by the telescope alone. For instance, it has enabled us to know that many stars are actually double stars, although they are too close together for even the largest telescope to show them as separate objects.

CHAPTER XXV

THE TELESCOPE

THE most important instrument to an astronomer is, of course, the telescope (from the Greek *tele*, "at a distance," and *skopeo*, "I view"), for with it astronomers have obtained most of their knowledge. Strange to say, we do not definitely know who invented this valuable instrument. According to one story it was invented accidentally. It is said that some three hundred years ago there lived in the town of Middelburg, in Holland, a spectacle-maker named Hans Lipperhey. One day during his absence his apprentice was playing with some spectacle glasses, and he so arranged them that the clock of a neighbouring church seemed quite near when viewed through the glasses. The apprentice told his master of his experience, and Lipperhey then made the first telescope. People did not think of looking at the stars with the new instrument, but instead they thought how useful it would be in time of war. With a telescope their generals would be able to see from a distance what the enemy's soldiers were doing, or they would be able to detect the approach of an enemy fleet before it could be seen by the naked eye.

The discovery quickly became known all over Europe,

PLATE XLI.—A STAR CLOUD IN THE MILKY WAY.
Could you count the stars in this photograph?
(*Photograph by E. E. Barnard.*)

PLATE XLII.—TWO TELESCOPES BELIEVED TO HAVE BEEN MADE BY GALILEO.

PLATE XLIII.—THE 40-INCH REFRACTING TELESCOPE AT THE YERKES OBSERVATORY.

PLATE XLIV.—THE 100-INCH REFLECTING TELESCOPE AT MOUNT WILSON OBSERVATORY.

and the principle of the invention soon reached the ears of Galileo, who set to work to make himself one of these new instruments. In 1609 he completed one that magnified about three times, which is not even as powerful as opera-glasses of the present time. Galileo did not care about soldiers or enemy fleets, but instead he applied his instrument to the heavens. Even such slight optical aid enabled him to realize the importance of the discovery, and he soon determined to make a larger and more powerful instrument, constructing a telescope that magnified thirty times. With it he discovered the mountains on the Moon, four satellites of Jupiter, saw more stars in the Pleiades, watched the changes in the appearance of Venus, and discovered spots on the Sun. He also saw Saturn " like an olive," as you will remember reading in an earlier chapter of this book. The finest and largest telescope that Galileo made magnified only 38 diameters—not as much as one that to-day can be bought for £2 or £3. Yet the discoveries he made with these crude instruments changed the outlook of the world and made astronomical history.

In the Tribuna di Galileo in Florence are two telescopes that are believed to have been made by Galileo (Plate XLII.). Below them on the stand on which they are exhibited is mounted the object-glass with which Galileo discovered the satellites of Jupiter. This you will see in the centre of the ivory frame, in the illustration.

There are two kinds of telescopes at the present day. Galileo's type is called the refractor, the other type being the reflector invented by Sir Isaac Newton. The re-

fractor is the ordinary "spyglass" kind of instrument that we look through, but the reflector is made on a different principle, as we shall shortly see. The largest refracting telescope is that of the Yerkes Observatory near Chicago, U.S.A. (Plate XLIII.). The object-glass, on which the power of this class of telescope depends, is 40 inches in diameter. A telescope is like a funnel that is placed in the neck of a bottle and put out in the rain. You know that a bottle will very soon become filled with water with a funnel to collect the raindrops, and the larger the funnel the sooner will the bottle become filled. It is similar with a telescope, for the object-glass collects the rays of light from a distant object, bringing them to a focus at the eyepiece of the instrument. It is through this eyepiece that the astronomer looks.

Now a few words about the other type of telescope, the reflector. It has a large mirror mounted at the bottom of an open tube. The mirror is so formed that when the rays of light from a star fall on it they are reflected to the top of the tube. A tiny mirror called "the flat" catches the rays from the large mirror and diverts them to the side of the tube, where the eyepiece is placed. Instead of looking *through* a reflecting telescope, we look *into* the side of the tube, and there see the object to which the telescope is directed.

Reflecting telescopes have several advantages. They can be made larger than refractors, and—size for size—they do not cost as much. Until comparatively recent times the largest reflecting telescope in the world was that of Lord Rosse, in Parsonstown, Ireland, the

mirror of which was 6 feet in diameter, and weighed 3 tons! It was outclassed by the great Hooker telescope on the summit of Mount Wilson, one of the highest peaks in the Sierra Madre range. The mirror of this great instrument has a diameter of 100 inches (Plate XLIV.), and it is estimated that it is sufficiently powerful to be capable of revealing more than a thousand million stars, and thousands of "island universes" beyond the Milky Way.

Throughout this book you will see photographs of the Sun, Moon, stars, and nebulæ, and perhaps you will have wondered how they are obtained. You will know that in a camera there is a lens. This may be called the "eye of the camera," for through it the camera is able to "see" the picture that is to be registered on the photographic plate. Naturally, larger lenses pass more light to the sensitive plate than small ones. Now the object-glass of a telescope is really a very big lens mounted in a tube. When observing, the astronomer uses the light it collects by mounting a smaller lens, or "eyepiece," at the other end of the telescope. If he places a photographic plate in position at the end of the tube the rays of light fall on it instead of passing through the eyepiece to his eye. Then he obtains a photograph of a star, or of the object to which the telescope is directed.

Before the invention of photography astronomers had to make all their pictures by drawings, using pen or pencil as the case might be. You will know how easy it is to make a mistake in making a drawing, and it is even easier to err when drawing such a delicate object

as, say, a nebula. When it became possible to photograph these objects, however, not only could we be sure of obtaining a correct picture, but also of obtaining it a great deal quicker than under the old method. Sometimes to make one drawing required some hours' observation. One astronomer, for instance, who made a beautiful map of the Moon, required twenty years to complete the work. Nowadays, photography enables us to get a similar series of pictures in as many minutes, effecting a great saving of time to the astronomer as well as providing a more accurate record.

Yet another advantage is due to the fact that the photographic plate is able to "see" objects that are invisible to the human eye owing to their extreme faintness. For instance, Jupiter's eighth satellite is so tiny, and so far away, that no one has ever yet seen it! We know it is there, because it has been photographed many times. When we look at the nebulæ through a telescope, they seem like faint patches of misty light. Photographs show them to be great bodies of fiery gas, covering a much wider area than appears to the eye, and clearly showing parts that are invisible. One of the reasons for this is that the human eye only gets a glance at an object, and very soon becomes tired with the strain of looking. The photographic plate never tires, however, no matter how long it is exposed on an object. Thus the astronomer is able to expose a plate on a nebula for perhaps six or eight hours, or even longer. During the exposure the rays of light from the nebula fall on the sensitive plate, building up an image all the time. Thus, in the finished photograph,

instead of just a glance, we see the result of hours of observation accumulated on the photographic plate.

A difficulty that has to be overcome before the astronomer can take long-exposure photographs is caused by the Earth turning on its axis. We have already seen that the stars rise and set. They are in constant movement across the sky, and even to the unaided eye the movement is distinctly noticeable. You can prove this for yourself. Note the position of some bright star—say Vega or Sirius—and move about until it is nearly hidden by a chimney or a tree. Stand still a few moments and you will see the star move towards the chimney, and suddenly it will disappear behind it.

If you take a picture of the stars with an ordinary camera, directing it, say, to the Pole Star, and exposing the plate for a few hours, you will not get a photograph of round dots, as you might expect. Instead, you will find on the plate long lines, part of a circle, for the stars will have moved during the exposure (see Plate XXIII.). Therefore, when the astronomer wants to make a long exposure on the stars, he has to fit some mechanism to the telescope, so that it will automatically turn it in the same direction as that in which the stars appear to be moving and at the same speed. By this means he overcomes the effect of the rotation of the Earth, and the consequent movement of the stars through the sky. All large telescopes are fitted with a mechanical device—generally electric motors—to turn the instrument for the purpose I have mentioned.

CHAPTER XXVI

THE OBSERVATORY AND ITS INSTRUMENTS

THE users of some of the early telescopes were puzzled as to how they should house them, for their telescopes were of great length. They racked their brains without success, and many of the larger instruments being left in the open air soon suffered from exposure to the weather.

It is very necessary to protect the telescope, and to-day great thought and care are expended in planning and erecting the buildings that house these instruments. The difficulty of being able to direct a telescope to any desired part of the heavens is overcome by using a dome (Plate XLV.). This enables the instrument to be directed to any celestial body, whether it be low or high in the heavens, or in any direction. If an ordinary roof were used the astronomer would have to lift it off every time he wanted to observe, and this would entail a loss of time as well as a great deal of trouble. In the case of the larger telescopes it would be impossible, owing to the enormous size and weight. The dome is erected on a circular-shaped building, in which the telescope is housed. It is generally made of some light metal, and revolves on wheels or some such device that allows it to be moved easily.

In the side of the dome there is a long slit extending from the bottom to the top, and covered with a sliding panel or shutter. All the astronomer has to do is to move the shutter to one side, and then revolve the dome until the slit faces in the desired direction. The telescope is then directed through the slit, and all is ready for observing. In Plate XLVI. is a view of the dome of the 100-inch reflecting telescope at Mount Wilson, showing the shutter open. You will see the telescope inside the dome, and you can gain some idea of its enormous size by noting the tiny figure of the astronomer (in white coat) standing on the platform near the eyepiece. An assistant stands at the rails outside the dome, near the left-hand half of the shutter.

No doubt you will be wondering how an astronomer is able to find any particular star that he wishes to observe, considering the great number of stars in the sky. Or, if he is looking at some star, you may wonder how he can tell whether or not the star is one that has been seen before. As we have already learned, the bright stars are known by a letter of the Greek alphabet. The smaller ones are generally referred to by a number taken from a catalogue of stars. The stars may be identified by determining their place in the heavens by measurement. If the captain of a ship encounters a derelict ship floating in the sea he will enter in his log the latitude and longitude of the dangerous object, and will be able to warn the captains of other ships of its position. Latitude is an expression of the distance of any point on the Earth's surface north or south of the equator. Longitude is the distance of any point east or

west of the meridian of Greenwich. These two terms enable us quickly to locate any point on land or at sea, and they are very necessary to geographers and sailors. In something the same way as the Earth is divided up into latitude and longitude, so is the sky mapped out. The celestial terms of measurement are termed Declination and Right Ascension. If an astronomer knows these two quantities of any particular star he will have no difficulty in finding its position, or alternatively in identifying some particular star he sees in his telescope.

In order to find a given place or object it is of the greatest importance both for a sailor and an astronomer to have the correct time. Should the observatory clock be only a second fast or slow, the calculation of position will be in error. Because of this requirement all observatories have an accurate time-keeper, called the sidereal clock. This is very delicately regulated, and is proof against changes of temperature due to the weather. These clocks are always of beautiful workmanship, and are very expensive. The broadcast time signals are sent out electrically by the clock at Greenwich Observatory.

The clocks themselves are kept accurate by the astronomers, who obtain their time from the stars. The necessary observations are made with a transit instrument, which is really a small telescope so arranged that it can be moved only in a north and south direction over the face of the sky. That is to say, although one may move the telescope up and down, it cannot be moved to left and right, for it is set on the celestial meridian,

PLATE XLV.—THE DOME AT THE MOUNT WILSON OBSERVATORY.

PLATE XLVI.—THE DOME OF THE 100-INCH REFLECTING TELESCOPE AT THE MOUNT WILSON OBSERVATORY, SHOWING THE SHUTTER OPENED.

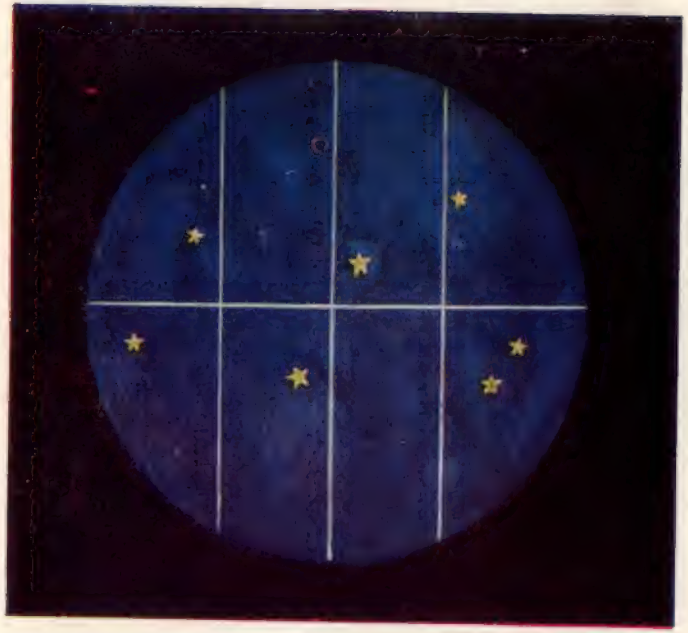

PLATE XLVII.—THE VIEW THROUGH A TRANSIT INSTRUMENT

(From a painting by Ellison Hawks.)

(Note: Through a telescope stars appear as discs of light, and the "points" as seen in the above illustration are really an optical illusion.)

or the great circle of the sky passing through the North Pole and the zenith, as the point directly overhead is called. In the eyepiece of this transit instrument are some very fine lines (Plate XLVII.). Now, mathematicians are able to calculate the exact instant that any given star should cross the meridian. As the centre wire in the eyepiece of the transit telescope is really the meridian, it follows that when a certain star—let us say Vega—passes this central wire, the astronomer knows that the time is exactly, say, 8 hours 5 minutes and 2 seconds. Not only are seconds taken into account, but fractions of seconds also. It is part of the work of an observatory to take a number of transits each night, and so keep a close check on the clock. In the accompanying picture you will see a bright star just about to cross the meridian, while some others have just passed it, and two more are yet to travel over the central wire.

CHAPTER XXVII

FAMOUS OBSERVATORIES

NEARLY every country in the world has a large observatory, maintained by the government or by gifts from some wealthy man. The Royal Observatory at Greenwich, near London (Plate XLVIII.), was founded as long ago as 1675. The first Astronomer Royal was John Flamsteed (1676–1719), and he was followed by Edmund Halley (1719–42), of whom we have already read. The chief work at Greenwich has always been to assist navigation, and—strange though it may seem—it is largely due to the labours of the astronomers at Greenwich that Great Britain obtained her commercial position and world-wide empire. The idea was that as the Moon revolves round the Earth in a month, it could be made to serve as a clock to give Greenwich time. If an Almanac could be produced predicting the exact position of the Moon among the stars, the navigator would possess a means of determining Greenwich time, and by subtracting this from local ship's time he would be able to determine his position.

At the time the observatory was founded—in the reign of Charles II.—the positions of the stars were not very accurately known, and this information was most necessary. The matter was brought to the king's notice,

and he commanded that Flamsteed should "apply himself with the most exact care and diligence" to the task of determining the exact position of the stars. Flamsteed was appointed Astronomer Royal at the very small salary of £100 a year, and he had full permission to provide himself with all the instruments he might require—at his own expense!

The work at Greenwich continues to be of a practical nature. One of the main things the astronomers do is to "look after" the time, and to see that "Greenwich Time" is broadcast so that the clocks and watches of the nation may show the correct time from day to day. The Observatory sends time signals at every hour of the twenty-four to the G.P.O., which distributes them throughout Britain. Greenwich Time is also broadcast by the B.B.C. at frequent intervals, in the form of six dot seconds. These emanate from a standard clock at the Observatory. In addition, through the powerful G.P.O. wireless station at Rugby, a series of precision signals is transmitted twice a day for the use of mariners. In the windows of many watchmakers there is a kind of telegraph needle that vibrates when time signals are sent from Greenwich. At some places the time is given by the dropping of a ball mounted on a short mast. On Merseyside the "one-o'clock gun," fired from Birkenhead, gives the time each day. It is fired by electrical connection with Greenwich.

Greenwich Observatory is situated on the meridian, the great circle around the Earth from which all other circles of longitude are measured east and west. If a navigator wishes to find his whereabouts on the wide

ocean, he must, of course, have some place from which to commence measuring, and för this point Greenwich meridian, or " Longitude O " as it is called, has been in use ever since the observatory was established.

Probably the most famous observatory in America is the Lick Observatory (Plate XLIX.), the origin of which is not without interest. A wealthy American, Mr. Thomas Lick, wanted to build a monument, so that after he died people would have something by which to remember him. Mr. Lick also wanted to build his monument on the shores of the Pacific Ocean, where it could be seen from the sea as well as from the land. Some wise men who heard of Mr. Lick's idea suggested to him that if America was at war the enemy's ships might fire on the monument and destroy it, and its builder would only be remembered by a heap of stones. As an alternative the wise men—who were really astronomers —suggested to Mr. Lick that he should build a large observatory. The suggestion was adopted and funds were left for its erection. After a good deal of experimenting to find a suitable place, the astronomers came to the conclusion that the best site was on the top of one of the peaks of Mount Hamilton, in California. So it came about that the great observatory was built on the top of this beautiful mountain. For many years the observatory has given to the scientific world a great amount of knowledge, and discoveries have been plentiful.

Mr. Lick made it a condition that the building should be thrown open to the public every week, and that visitors should be encouraged to come to look through

PLATE XLVIII.—THE ROYAL OBSERVATORY, GREENWICH.

the great telescope at the wonders of the heavens. When we hear that the observatory is situated on the top of a mountain that is over 4,200 feet in height, and that the nearest railway is thirty miles away, we should scarcely suppose that many people would take advantage of these conditions. It is to the contrary, however, for when the observatory is open, so the astronomers of the Lick Observatory tell us, a long string of vehicles of all descriptions may be seen down the valley, winding their way up the corkscrew path. Sometimes there are as many as three hundred visitors who come to view the beautiful objects to be seen in the sky through the great Lick telescope. Of course, the astronomers have to live at the top of Mount Hamilton, and so houses have been built for their accommodation near the observatory itself. Here they live for a certain length of time and then go "on leave" to their homes in the town of San José, thirty miles away.

Another well-known American observatory is the Yerkes at Williams Bay, Wisconsin. Although connected with the University of Chicago, the Yerkes Observatory is more than seventy miles distant from the city. The observatory contains the largest refracting telescope in the world. It is 50 feet in length, and its object-glass is 40 inches in diameter, or 4 inches larger than that of the Lick telescope. The dome that covers this giant is 75 feet in diameter, and the floor of the room weighs over 37 tons. The dome is turned by an electric motor, and the floor is so arranged that it can be raised or lowered as required by the observer.

CHAPTER XXVIII

CONCLUSION

AFTER we have considered all the wonders of the heavens there remains the important question, what does astronomy teach us about our Earth, for after all this is the place in which we live. As we know, day by day it travels around the Sun, accompanied by the Moon, and in the same manner as the other planets. But it cannot go on in this manner for ever. There must come a time when the "end of the world" will come to pass, but how or when this will take place we have not the slightest idea. Floating about in space are numbers of dark bodies, or dead suns, which are really stars that have burnt themselves out. Should our Sun collide with one of these bodies, then indeed such a heat would be generated that the Earth would speedily be "scorched to a cinder." There is another way in which the end of the world might come, and one that seems to be much more likely. Worlds have a "life" just as planets and animals have. They come into being, go through similar changes to our own "growing up," and at length there comes a time when they "die." The Moon is a dead world at the present time, for it has neither air nor water. Although Mars still has some water and a certain amount of atmosphere,

it is in a dying state. Slowly, very slowly, it is losing air and water, and the time will come when Mars, like the Moon, will be incapable of supporting any form of life.

It is only reasonable to suppose that the Earth also will lose its water and its atmosphere, and, as a matter of fact, it has been proved that it *is* actually losing them at the present time. At last there must come a time when there is neither air nor water on the Earth, and plants, animals, and men will no longer be able to live on its surface. Such a time, however, must be so far distant that we cannot form any idea of the period—millions of years must elapse before such a state of things comes to pass.

In conclusion, I hope that I have succeeded in showing you some of the things that astronomers have before them at the present time. I have told you of that mighty globe, our Sun, the source of light and heat, and the centre of a family of planets of which the Earth is one. I have told of the appearances of the different planets, some of which resemble the Earth to a certain degree, and others that are totally unlike it. The comets, with their mysterious "comings and goings," have been touched upon. I have dealt in turn with the stars themselves, those countless shining points of light—each one a sun, many of them perhaps greater and brighter than our own Sun; the nebulæ; and the Milky Way. Of course, in a little book like this, I have not been able to do anything but touch very simply on these wonders, and if you are interested in the planets or in the stars, or in the hundred and one other objects

that are to be found in the heavens, I would ask you not to let your interest drop, but to read other books that deal with these subjects more fully.

Perhaps some day you will come to possess a telescope, and then you will find new wonders opened out to your admiring gaze. A small telescope is sufficient to show you many delightful things, and even a pair of opera-glasses will provide you with many a night's enjoyment out of doors. For comets a pair of good field-glasses are, in some respects, even better than a telescope, because the telescope will show only a part of a comet at a time, while a field-glass will show it in all its beauty. For those who have not even a field-glass, many interesting hours may be spent in learning the constellations thoroughly—as the Chaldean shepherds learned them—with the unaided eye, while a watch of an hour or two on a suitable night is almost certain to be rewarded by the sight of at least a few shooting stars.

PLATE XLIX.—THE LICK OBSERVATORY, MOUNT HAMILTON.

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